United States General Accounting Office

GAO

Report to the Honorable
Harry Reid, U.S. Senate

February 1992

HIGH-SPEED GROUND TRANSPORT

Acquiring Rights-of-way for Maglev Systems Requires a Flexible Approach

GAO/RCED-92-82

GAO United States
General Accounting Office
Washington, D.C. 20548

176009

Resources, Community, and
Economic Development Division

B-246563

February 10, 1992

The Honorable Harry Reid
United States Senate

Dear Senator Reid:

In response to your request, this report discusses the advantages and disadvantages of right-of-way alternatives for magnetic levitation (maglev) systems. It also recommends that the Secretary of Transportation establish a clearinghouse for collecting and disseminating information on these right-of-way alternatives.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will send copies to the appropriate congressional committees, the Secretary of Transportation, and the Administrator of the Federal Railroad Administration. We will also make copies available to others upon request.

This report was prepared under the direction of Kenneth M. Mead, Director, Transportation Issues, who may be reached on (202) 275-1000 if you or your staff have any questions. Other major contributors to this report are listed in appendix I.

Sincerely yours,

J. Dexter Peach
Assistant Comptroller General

Executive Summary

Purpose

A form of high-speed ground transportation—magnetic levitation (maglev)—could relieve highway and aviation congestion, conserve energy, and reduce air pollution. Maglev technology uses forces of attraction or repulsion from powerful electromagnets placed in either the maglev vehicle or the guideway beneath it. These forces both lift the vehicle above the guideway and propel it at speeds of up to 300 miles per hour. In the United States, a number of maglev systems are being considered, but difficulties in acquiring rights-of-way—the right to move across property and to erect associated facilities—may impede system implementation. Concerned about access to rights-of-way, Senator Harry Reid asked GAO to identify right-of-way alternatives and to assess the advantages and disadvantages of each. As part of this work, GAO reviewed the three U.S. maglev projects whose plans are most fully developed.

Background

As research and development efforts in Germany and Japan have brought maglev systems closer to commercial service, interest has grown, both in the United States and abroad, in using them to supplement or replace current transportation systems over distances of 150 to 500 miles. Several federal agencies have formed the National Maglev Initiative, a collaborative organization to advance U.S. maglev development. Moreover, the Congress recently authorized $725 million for developing maglev systems in the United States. However, to improve maglev's chances of economic success, rights-of-way that can accommodate maglev's high speeds must be acquired. Such rights-of-way must be relatively straight and level to meet passenger comfort requirements at high speeds. Moreover, technical, safety, environmental, and legal issues must be considered as various rights-of-way are proposed.

Results in Brief

Right-of-way options for maglev use fall into two categories: collocating with (sharing) existing rights-of-way—Interstate highways, railroad lines, and utility corridors—and acquiring new rights-of-way. Whether any particular option will prove advantageous will depend on local conditions. In some locations, Interstate highway rights-of-way may contain enough space to accommodate maglev guideways. In urban areas, rail lines may provide practical maglev routes into city centers. Electric utility corridors are widespread and could provide a nearby maglev power source. Over longer distances, however, existing rights-of-way—although they may be straight and level enough for maglev's high speeds in some areas—cannot be relied on exclusively, and new rights-of-way that allow such speeds will be needed.

For each of three planned maglev systems, the developers needed to be flexible and combine different right-of-way options. A system connecting Anaheim, California, to Las Vegas, Nevada, would collocate with an Interstate highway over much of the route. Where highway collocation is unsuitable, the system would follow railroad lines or establish new rights-of-way. The proposed Orlando, Florida, maglev system would collocate with electric utility lines and a county toll road, as well as obtain new rights-of-way. A system connecting downtown Pittsburgh, Pennsylvania, to the Pittsburgh International Airport would collocate with existing railroad lines as well as establish new rights-of-way, including some that would require tunnels.

Although right-of-way requirements for each project will differ, sharing information about right-of-way options and acquisition could expedite development of maglev systems and minimize duplication of planners' efforts. Such sharing might also facilitate development of other high-speed ground transportation systems, which face some of the same right-of-way issues as maglev. The Department of Transportation could contribute to maglev development by collecting such information and making it available to planners.

GAO's Analysis

Right-of-way Options for Maglev Systems Vary in Suitability

Several maglev proponents believe that existing highway rights-of-way offer an affordable solution to the siting problem. An extensive network of Interstate highways already exists, and many Interstate rights-of-way contain enough space in medians or parallel to highway shoulders to accommodate a maglev system. However, the cost of collocating with highways is not easy to calculate because it must include the cost not only of gaining access to the right-of-way but also of conforming the guideway to the highway and of acquiring new land in areas where collocation is not practical. Also, Interstate highways, which were designed for speeds of about 70 miles per hour, often cannot accommodate maglev's need for a straight and level route over long distances. In addition, some highway officials are concerned about the safety implications of siting a high-speed maglev system close to drivers on the highway, who may be startled by passing maglev vehicles.

In some locations, existing railroad rights-of-way may offer suitable siting options for maglev systems. In urban areas, where new rights-of-way are difficult and costly to obtain, rail lines may provide a direct and relatively inexpensive route into and out of city centers, as well as into downtown transportation centers connecting to other modes of travel. Railroad officials said they would consider sharing rights-of-way with maglev systems, although they had some concerns about the safety of operating a maglev system adjacent to railroad tracks. Like Interstate highways, railroad lines were not designed for maglev's high speeds and cannot meet maglev's need for a straight and level route over long distances. Also, officials of several transit agencies that have right-of-way sharing agreements with railroads stated that negotiating those agreements was more costly and time-consuming than anticipated.

Maglev systems could also be located in electric utility corridors. Such corridors may offer an advantage by providing a nearby maglev power source. However, because many utilities do not own the land on which their lines are located, negotiations for rights-of-way would have to occur with many different landowners. Also, some electricity lines traverse rough terrain and turn on sharp angles, making them unsuitable for maglev systems.

Where existing rights-of-way are neither available nor compatible with maglev systems, new routes will be needed. A new right-of-way would allow engineers to design a route that best meets maglev's speed and ride comfort requirements, thereby making maglev more competitive. A new right-of-way, however, may be less benign environmentally than other options because it could disturb previously undeveloped areas. Also, acquiring new rights-of-way may entail legally complicated and time-consuming negotiations with many landowners and government agencies.

Planned Maglev Systems Will Need a Mix of Rights-of-Way

Because right-of-way options available to and appropriate for maglev will vary from one location to another, ready access to one type of right-of-way will not solve all acquisition problems. For example, although providing low-cost or free access to Interstate highway rights-of-way may benefit systems whose routes rely on such access, it will not remove all barriers to right-of-way acquisition. The three planned systems that GAO reviewed would each need to use more than one right-of-way option, including acquiring new land. Cost, topography, the availability of existing transportation corridors, and potential station locations influenced the decisions to use a flexible approach incorporating multiple rights-of-way.

The proposed maglev line from Anaheim, California, to Las Vegas, Nevada, would combine Interstate highway, railroad, and new rights-of-way. The system would parallel Interstate 15 for over half of the route's length, thereby minimizing impacts on surrounding federal lands, which contain habitat for the threatened desert tortoise. In at least one location where the system enters a station, it would follow railroad rights-of-way. Where the highway's curvature is not suitable for maglev, new rights-of-way would have to be established. If such rights-of-way pass through public lands, consultation with and/or approval from federal and state resource agencies would be necessary.

The Orlando maglev system illustrates that even a short system in a developed area will need to piece together its route. This 13.5-mile maglev project will share rights-of-way with utility lines and a toll road, as well as establish rights-of-way through private and airport lands. Although utility lines may not offer suitable siting options in all areas, they offer the Orlando system a straight route that will allow it to reach its top speed of 250 miles per hour.

Because the maglev line between the Greater Pittsburgh International Airport and downtown Pittsburgh will pass through developed areas into a city center, existing railroad lines may present a practical siting option. However, because the railroad routes were not designed for maglev's high speeds, the maglev system may forfeit high speeds in favor of access to existing rights-of-way. Furthermore, in the hills around Pittsburgh, this system will probably need new rights-of-way with significant earthworks, such as tunnels, to enter the airport area.

Recommendation

GAO recommends that the Secretary of Transportation, as part of the National Maglev Initiative, establish a central clearinghouse for information collected on rights-of-way for high-speed ground transportation systems. This information, particularly that based on actual experience, should be made available to system planners through mechanisms such as newsletters, conferences, and transportation research centers.

Agency Comments

GAO met with Federal Railroad Administration officials, who generally agreed with the contents of this report. As appropriate, GAO amended the text to reflect their comments. However, as agreed with Senator Reid's office, GAO did not obtain written agency comments.

Contents

Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
DOT	Department of Transportation
EDS	electrodynamic suspension
EMF	electric and magnetic field
EMI	electromagnetic interference
EMS	electromagnetic suspension
FRA	Federal Railroad Administration
GAO	General Accounting Office
HSST	High Speed Surface Transportation
MTI	Maglev Transit, Inc.
NMI	National Maglev Initiative
TGV	Train à Grande Vitesse

Introduction

A relatively new form of high-speed ground transportation—magnetic levitation—may soon be introduced into commercial service. Commonly abbreviated as "maglev," this technology allows vehicles to travel at speeds of over 300 miles per hour along a fixed guideway. Most recent developments in maglev technology have occurred outside the United States, mainly in Germany and Japan, and companies in both countries are now marketing their maglev technologies worldwide. Plans by government and private organizations in the United States would place maglev routes around the country. Maglev proponents claim that maglev offers potential benefits, including reduced highway and aviation congestion, increased energy efficiency, and reduced pollution. The Congress recently passed legislation to facilitate maglev implementation. However, one challenge to maglev development is the need to acquire rights-of-way for maglev routes. As more proposals are made for maglev systems in the United States, the acquisition of rights-of-way is becoming a major issue—one that some believe could be critical for maglev implementation in this country.

Maglev Is a Form of High-Speed Ground Transportation

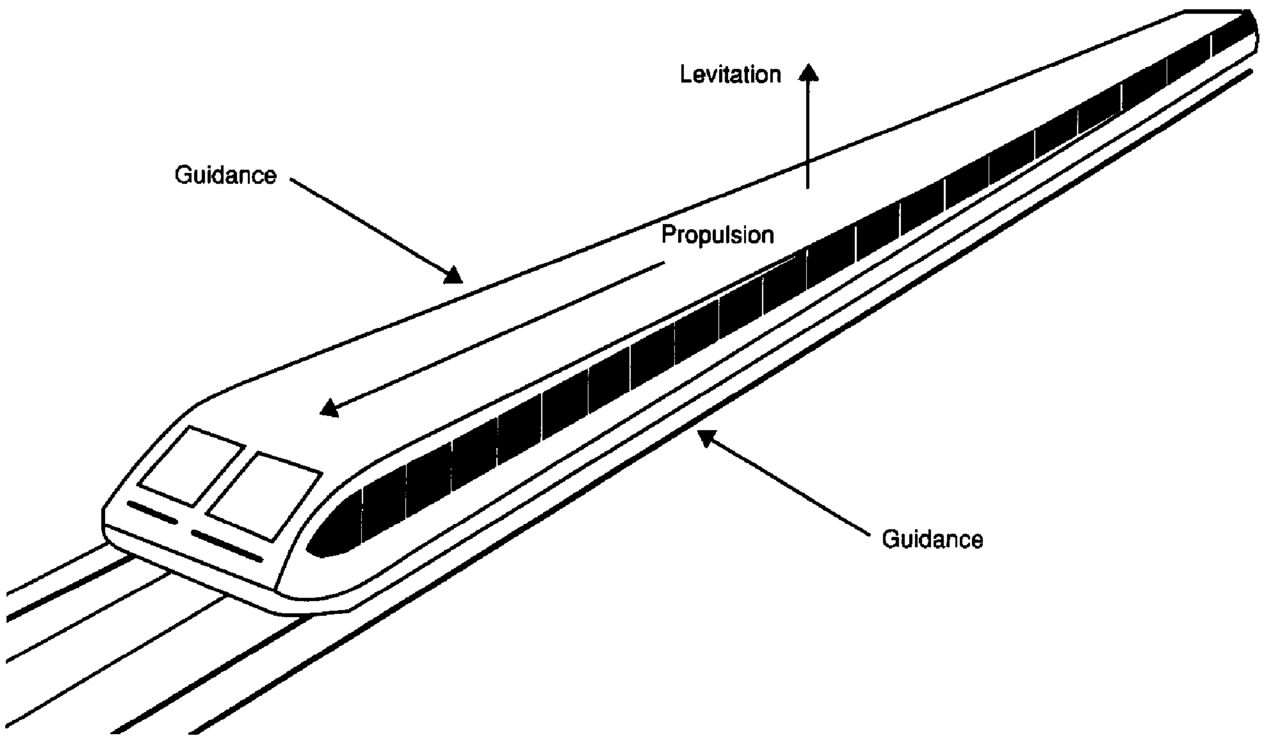
High-speed ground transportation is defined as a transportation system that maintains a sustained speed of at least 125 miles per hour. Such systems have operated overseas for several decades. In Japan, the Shinkansen, or "Bullet Train," has been carrying passengers since 1964. Similarly, France's "Train à Grande Vitesse" (TGV) has carried millions of passengers at speeds nearing 200 miles per hour since 1981. As of November 1991, neither system had ever had an accident resulting in a passenger fatality while operating at high speeds.[1] Several other nations, including Canada, Germany, Great Britain, Italy, Spain, and Sweden, have developed or are developing similar conventional rail high-speed train systems. In the United States, only one commercially operating ground transportation system meets the high-speed criterion. Amtrak's Metroliners reach speeds of 125 miles per hour over some stretches of the route between New York City and Washington, D.C. This is one of Amtrak's busiest and most profitable routes as well. Proponents of high-speed trains believe that a number of corridors in the United States could benefit from high-speed service.

Recently, a form of high-speed ground transportation known as maglev has received congressional and media attention. Maglev differs greatly from high-speed conventional rail technology because it does not run on parallel steel tracks and because it uses a different type of propulsion system. As

[1] In 1988, while entering a station on shared trackage at 64 miles per hour, the TGV had an accident that resulted in the death of the train engineer and one passenger.

figure 1.1 shows, maglev systems employ a vehicle that is suspended above and propelled along a fixed guideway by powerful electromagnetic fields. Because there is no physical contact between the guideway and the vehicle while traveling, there is very little friction, and therefore maglev vehicles can travel at sustained speeds exceeding 300 miles per hour.

Figure 1.1: The Three Primary Functions Basic to Maglev Technology



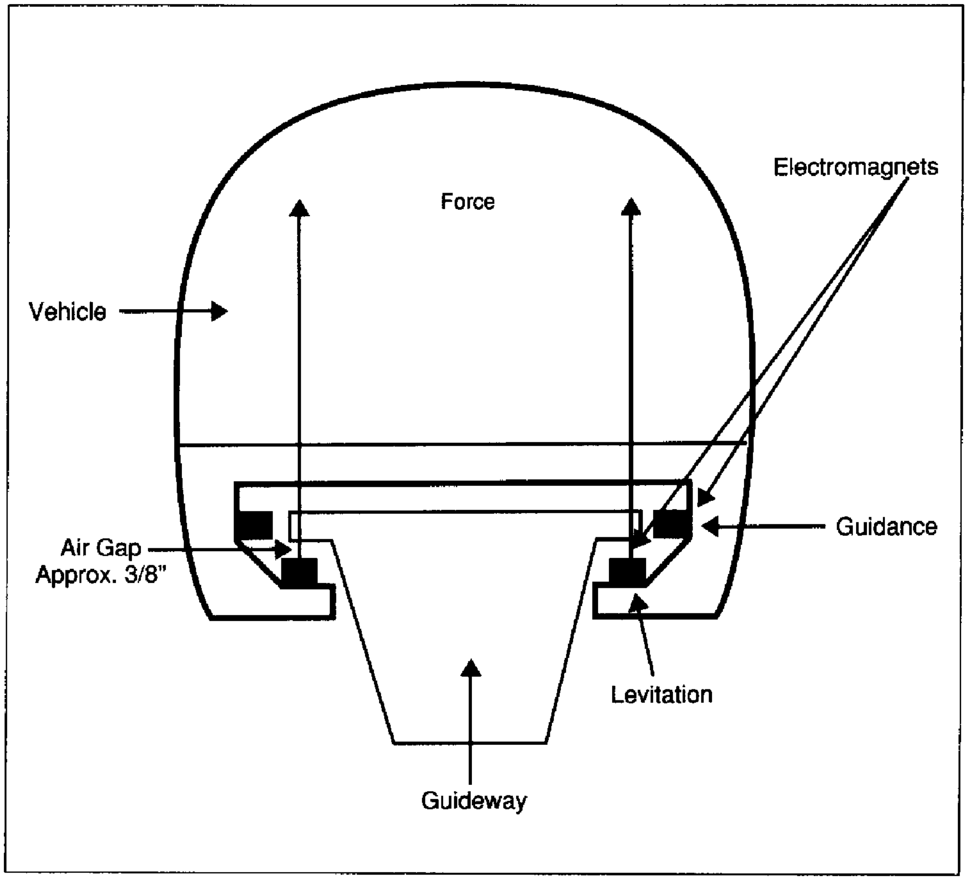
Source: Federal Railroad Administration.

Most recent maglev research and development has focused on two types of suspension systems: electromagnetic suspension (EMS) and electrodynamic suspension (EDS). These two technologies are not currently compatible because they require different types of guideway configurations (see figs. 1.2 and 1.3).

Electromagnetic Suspension (EMS) Maglev

EMS system development has been pursued principally in Germany. As figure 1.2 shows, EMS technology employs electromagnets mounted on the vehicle. When power is applied to the system, these electromagnets are attracted upward to ferromagnetic rails on the underside of the guideway and the vehicle is lifted. The vehicle then "floats" above the guideway as it travels. EMS technology is characterized by a small air gap (about 3/8 of an inch) between the vehicle and the guideway.

Figure 1.2: Electromagnetic Suspension Maglev



Source: Federal Railroad Administration.

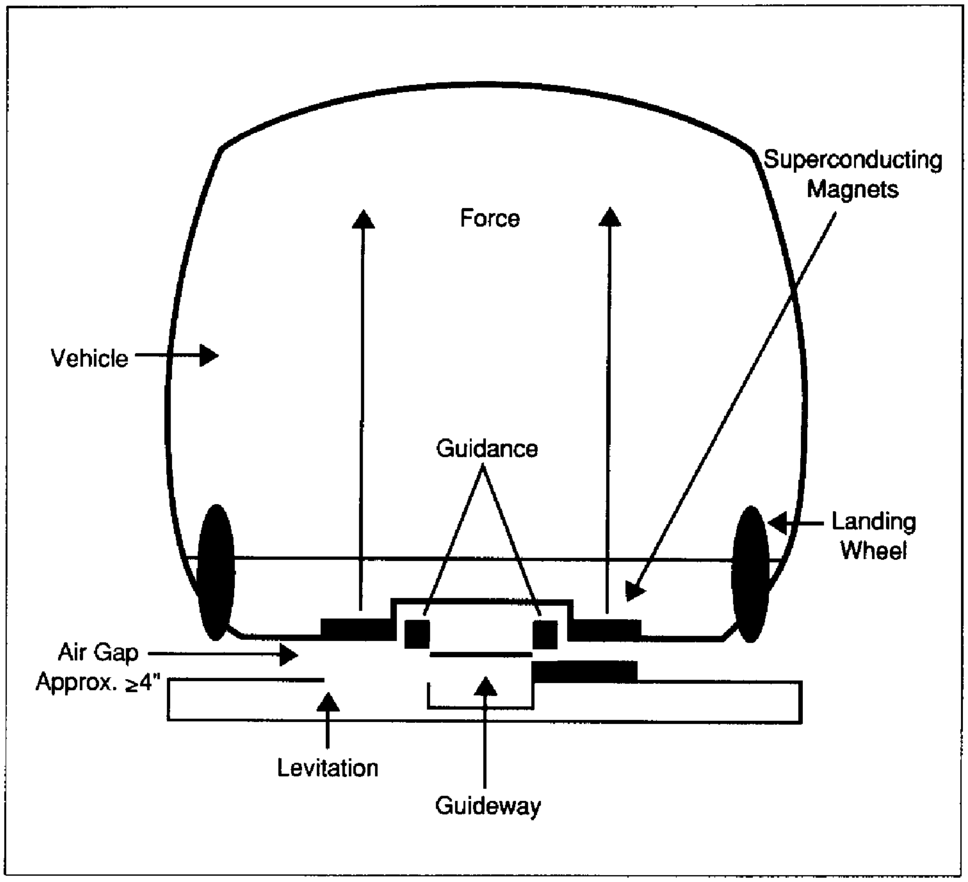
Electrodynamic Suspension (EDS) Maglev

EDS maglev technology has been pursued principally in Japan.[2] In contrast to the EMS system, the EDS system uses repulsive magnetic forces for levitating the vehicle (see fig. 1.3). When power is applied,

[2]Japanese industry has also developed and is currently marketing an EMS system, called High Speed Surface Transportation (HSST), which is discussed later in this chapter.

superconducting magnets mounted on the vehicle interact with a conductive guideway, producing vehicle levitation. EDS is characterized by a relatively wide air gap (about 4 inches) between the vehicle and the guideway.

Figure 1.3: Electrodynamic Suspension Maglev



Source: Federal Railroad Administration.

Maglev Propulsion System

The propulsion systems employed in the German attractive and Japanese repulsive maglev technologies are similar. In both cases the maglev vehicle effectively rides on an electromagnetic wave using a linear synchronous motor. The linear motor generates a magnetic traveling field. Current in a set of magnets generates an electromagnetic moving field by which the vehicle is pulled along. Vehicle thrust (speed) can be controlled by changing the intensity and frequency of the current. Raising the frequency of the current speeds up the vehicle. Reversing the poles of the magnetic field reverses direction, which provides braking. Two forms of this propulsion system are employed today. The first is known as a "long-stator" system, in which the magnetic windings that produce the propulsive force are built into the guideway. This system, employed by the German Transrapid maglev, is also known as an active guideway system. The other propulsion form is the "short-stator," or passive guideway, system, in which the magnetic windings are in the vehicle and the non-powered components are in the guideway. A Japanese maglev system, "High Speed Surface Transportation," or HSST, employs this design.

Recent Maglev Efforts Have Been Foreign-Based

From the 1960s through the mid-1970s, the United States was a world leader in maglev research. Under the High Speed Ground Transportation Act of 1965 (P.L. 89-220), through the early 1970s, the Federal Railroad Administration (FRA) funded research in different forms of high-speed ground transportation, including maglev. Among the early research that FRA sponsored was work in EMS and EDS levitation systems. FRA also sponsored research leading to the development of the linear electric motor, the propulsion system employed by current maglev prototypes. In 1974, a linear motor vehicle reached 255.4 miles per hour at the Department of Transportation's (DOT) Transportation Test Center in Colorado. The National Science Foundation also sponsored maglev research leading to the production of a scale model maglev concept called "Magneplane." The Magneplane concept featured enhanced maneuverability around curved guideways and is currently being revived by a private concern in the United States. In 1975, federal funding for U.S. high-speed maglev research was suspended, and American industry virtually abandoned its interest in maglev. From this point, other countries, notably Germany and Japan, pursued maglev research and development.

Germany has spent over $1 billion on a single maglev concept—the "Transrapid" maglev development program. The development of high-speed maglev technology in Germany began in the late 1960s and early 1970s. The first public demonstration of the "Transrapid 05" maglev vehicle took place at the 1979 International Transport Fair in Hamburg, Germany. In 1984, the first 13 miles of a test guideway at Emsland, Germany, were completed, and testing of the new "Transrapid 06" maglev vehicle began. This facility was completed in 1987. In 1989, testing of the latest generation maglev, the "Transrapid 07," began. In December 1989, the Transrapid 07 achieved a speed of 270 miles per hour. Also in December 1989, the German government approved the first commercial Transrapid application, an 82-kilometer route between the Koeln/Bonn airport and the city of Essen. Plans call for the first phase of this project to connect the Koeln/Bonn and Duesseldorf airports.[3] Additionally, Transrapid is marketing its system for commercial application in the United States.

Japan, in contrast to Germany, has developed several maglev concepts simultaneously by doing research in superconducting magnet and other maglev technologies. In the early 1970s, experiments with superconducting maglev (EDS) technologies were begun, leading eventually to the testing of three maglev vehicles. The first vehicle demonstrated the feasibility of using superconducting magnets for maglev. In 1979, the vehicle achieved a speed of 320 miles per hour on a test track in Japan. Considerable advances have since been made, and currently a test track for the superconducting maglev vehicle of approximately 40 kilometers is under construction; testing should begin by 1993. The Japanese project that a maglev system could link Tokyo and Osaka by the year 2000.

The Japanese also conducted research and development on a nonsuperconducting maglev technology (EMS), which is similar to the German Transrapid technology. Work began on this HSST system in 1975, and by 1989 the system had been sufficiently developed to allow the Japanese to begin marketing it internationally. The HSST program calls for developing for commercial use four different maglev systems with operating speeds of between 100 and 400 kilometers per hour. A few HSST low-speed demonstration vehicles have been introduced into exhibition service during the past decade.

U.S. Progress in Maglev Development and Implementation

Since the mid-1970s, federal efforts have been confined mainly to gathering and disseminating information and providing limited funding for individual project feasibility studies. Government and private organizations in the United States are just beginning to devise a comprehensive structure and financial foundation for maglev development and implementation. In line with the Administration's 1990 National Transportation Policy, maglev projects are being pursued by nonfederal entities, such as states and local or regional consortia.

The Rail Safety Improvement Act of 1988 (P.L. 100-342) defined maglev systems as "railroads" and assigned responsibility for regulating their

[3]According to FRA, as of November 1991, three Transrapid systems were planned for routes within Germany: (1) Hamburg to Berlin, (2) Bonn to Berlin, and (3) the original Koeln/Bonn airport to Essen route.

safety in the United States to FRA. However, no maglev systems currently operate in the United States, and safety standards have not yet been developed. Currently, FRA is cooperating with German maglev developers to assess maglev safety issues and performance, since any near-term maglev systems in the United States would probably use German or Japanese technologies. For example, in November 1990, FRA issued a preliminary safety review of the German Transrapid maglev system.

In 1990, the federal government established the National Maglev Initiative (NMI), which is an interagency cooperative group composed principally of representatives from FRA, the Army Corps of Engineers, and the Department of Energy. With FRA as the lead agency, NMI's mission is to develop a public-private partnership to determine the appropriate role of maglev in the nation's transportation future. NMI is expected to assess the engineering, economic, and environmental aspects of maglev; determine maglev's feasibility and appropriate place in the national transportation system; and stimulate the development of a U.S. maglev system suitable for commercial application in this country by the year 2000. Also, issues concerning right-of-way needs and acquisition are being explored and developed.

Increased Federal Funding Has Recently Accompanied U.S. Interest in Maglev

The Congress recently passed the Intermodal Surface Transportation Efficiency Act of 1991 (P.L. 102-240), which mandates that a National Magnetic Levitation Prototype Development Program be administered jointly by DOT and the Army Corps of Engineers through a national maglev project office. The act authorizes $725 million for a program to construct an operating prototype high-speed maglev system. Under this measure, $225 million would be authorized for this system from the general Treasury, and $500 million would come from the Mass Transit Account of the Highway Trust Fund. The act also establishes a federal high-speed ground transportation policy, which calls for designing and constructing a maglev technology capable of operating along federal-aid highway rights-of-way. Additionally, it authorizes states to waive fees or charges for allowing maglev systems to use federal-aid highway rights-of-way.

The revived U.S. interest in maglev has also been accompanied by renewed federal funding for federal research and development. For fiscal year 1991, the Congress appropriated $10 million for FRA research and development in maglev, including work in maglev safety.[4] Also for fiscal year 1991, the Army Corps of Engineers allocated $2 million of its appropriation for support work under NMI. For fiscal year 1992, FRA's maglev/high-speed rail research and development appropriation increased to $12 million, including $2.5 million for five state planning grants.

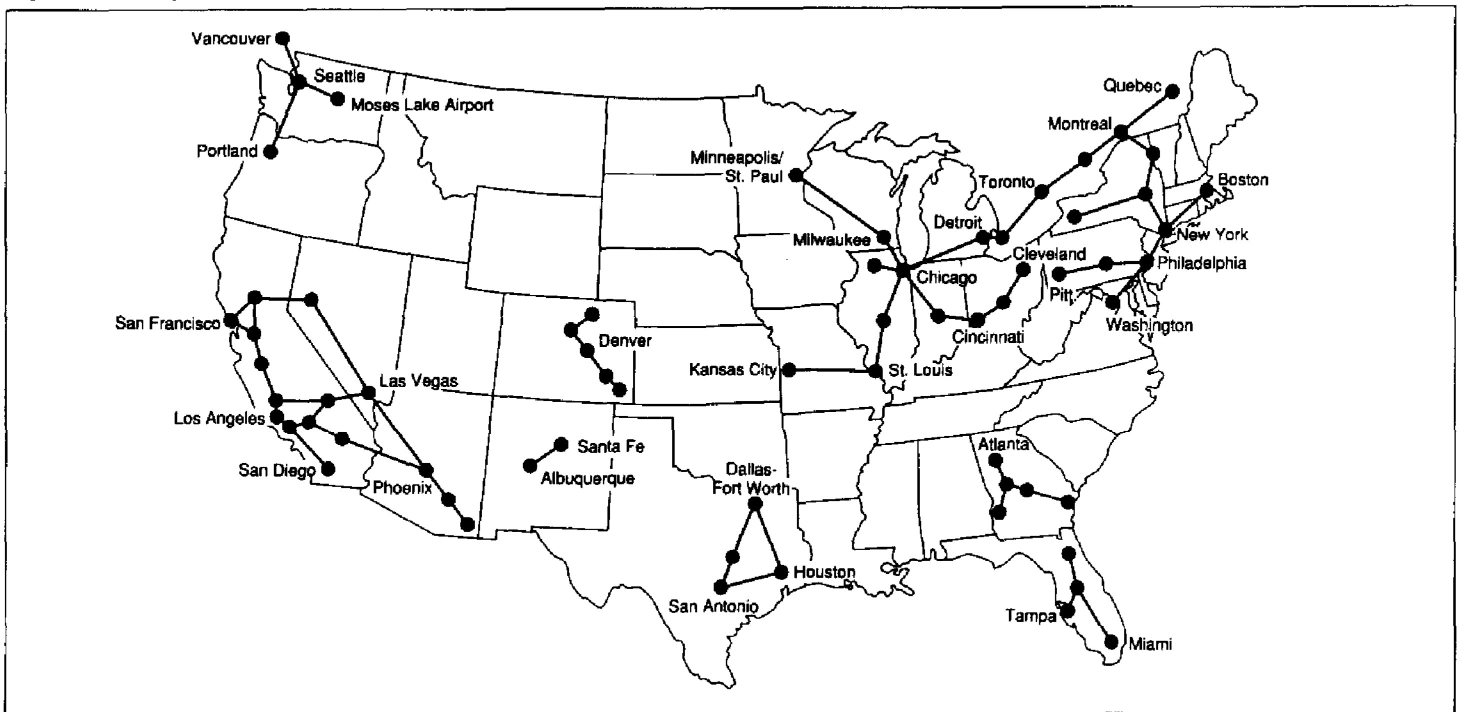
Currently, the organizations pursuing maglev projects are receiving most of their funding from state and other sources. For example, officials of the consortium proposing a maglev demonstration project from downtown Pittsburgh, Pennsylvania, to the Pittsburgh airport told us that they have raised over $1 million from local public and private sources. The organization planning the maglev system between Anaheim, California, and Las Vegas, Nevada, envisions raising the majority of its capital from private sources. Additionally, New York State recently funded a study that proposed using a maglev technology employing tilting vehicles for high-speed routes in that state. Such tilting vehicles may allow systems to be built along routes designed for other transportation modes.

Proposals for U.S. Maglev Systems

Both government and private organizations have proposed a number of maglev systems, as well as other high-speed ground transportation systems, for routes throughout the United States (see fig. 1.4).

[4]According to FRA, $500,000, or 5 percent of this appropriation, was obligated for high-speed rail safety research.

Figure 1.4: Proposed North American High-Speed Ground Transportation Routes



Note: Includes all recent proposals for high-speed ground transportation systems; for many of the routes, planners have yet to determine the appropriate technology—maglev or conventional high-speed rail.

Source: High Speed Rail Association.

Three maglev projects in particular are in advanced planning stages. A high-speed maglev system that would run between Anaheim, California, and Las Vegas, Nevada, is in a more advanced planning stage than any other proposed U.S. intercity maglev system. In Florida, the governor has authorized advanced planning activities for a high-speed maglev "demonstration" line linking the Orlando airport to the major commercial area near Walt Disney World. This may become the first high-speed maglev project to operate commercially in the United States. Finally, another maglev "demonstration" line from downtown Pittsburgh, Pennsylvania, to a new terminal under construction at the Greater Pittsburgh International Airport is currently being studied. This line would be the first leg of an extensive interstate high-speed maglev system, with Pittsburgh as its hub. The developers of all of these systems propose to use existing German Transrapid maglev technology.

Right-of-way Acquisition Is a Significant Issue

Acquisition of rights-of-way for transportation projects, particularly highways, has been cited by GAO and others as an important issue. In 1988, we reported that a continuing need exists to build new highways and improve existing ones.[5] The costs of acquiring the necessary rights-of-way for highway projects can represent a sizeable portion of highway construction costs. We reported that federal and state highway officials estimated that right-of-way acquisition costs account for more than 10 percent of project costs for highways requiring such acquisition and, in some urban areas, could account for 50 percent of an individual project's cost. We further reported that for complex highway projects, meeting environmental requirements under the National Environmental Policy Act of 1969 (P.L. 91-190) can take 5 years or more, a period during which the costs of a right-of-way can increase dramatically because of inflation, development, and/or speculation.

Similarly, in 1990, the American Association of State Highway and Transportation Officials (AASHTO) reported that surface transportation demand is expected at least to double by the year 2020 and in urban areas alone, 178,000 additional lane-miles of highway will be needed by 2005. AASHTO stated that in order to meet even a small part of this demand, surface transportation corridor preservation strategies will need to become an integral part of the transportation planning and project development processes.[6]

Thus, for projects such as maglev systems that require some new rights-of-way, acquiring land is likely to be a significant issue. For example, only one of the previously mentioned systems—the Orlando system—has actually gained access to some of its needed rights-of-way. Some believe that the economic and institutional barriers to acquiring rights-of-way for maglev systems may impede the development of maglev systems in this country. Consequently, right-of-way acquisition is an important issue to consider as maglev implementation efforts advance.

Objectives, Scope, and Methodology

In a December 1990 letter to GAO, Senator Harry Reid expressed concern that problems associated with acquiring rights-of-way could block maglev implementation and asked us to examine the alternatives for acquiring maglev rights-of-way. As agreed with the Senator's office, we identified the principal alternatives for maglev rights-of-way and assessed the advantages and disadvantages associated with each. As part of this work, we reviewed

[5]Highways: Acquiring Land for Federal-Aid Projects (GAO/RCED-88-112, Mar. 30, 1988).

[6]American Association of State Highway and Transportation Officials, Report of the AASHTO Task Force on Corridor Preservation (Washington, D.C.: July 1990).

three planned maglev systems in the United States. We limited our analysis to high-speed maglev technology. We did not attempt to judge the economic viability of any particular proposed maglev system or of maglev transportation in general.

To obtain expert views on maglev right-of-way issues, we met with officials of the National Maglev Initiative, including the Federal Railroad Administration and the Army Corps of Engineers. We also interviewed officials of the Federal Highway Administration and the Department of Transportation's Transportation Systems Center. We also obtained information from the Urban Mass Transportation Administration, the Department of the Interior, and the Interstate Commerce Commission. We interviewed officials of state, local, and/or private organizations affiliated with individual maglev projects. We also interviewed and obtained information from officials of the High Speed Rail Association. We reviewed technical research and literature pertaining to maglev construction, operation, and economics.

To obtain information regarding specific right-of-way options, we interviewed and/or obtained documents from officials of four major railroads, 16 utility companies, and four mass transit systems. We also interviewed officials of associations representing highway and utility interests. In addition, we discussed issues in this report with the Office of Technology Assessment and the Transportation Research Board of the National Research Council. Furthermore, because maglev and conventional high-speed rail systems have several issues in common, we reviewed data and literature from several conventional rail systems and interviewed officials affiliated with them.

To obtain an understanding of issues specific to individual maglev projects, we reviewed potential rights-of-way for three proposed maglev systems. On the basis of our interviews, literature reviews, and maglev site examinations, we identified criteria for evaluating the suitability of right-of-way alternatives for maglev systems and alternatives for maglev rights-of-way. Chapter 2 discusses these criteria and reviews the advantages and disadvantages of the right-of-way alternatives we identified. Finally, using the proposed systems we reviewed, we described right-of-way alternatives for particular maglev systems. Chapter 3 focuses on these systems and illustrates siting issues unique to each.

This report represents our analysis of currently available data on maglev technology as they apply to right-of-way requirements. However, potential future advances in maglev technology may affect parts of our analysis concerning the ability of maglev systems to use available rights-of-way. As appropriate, we note this limitation in our analysis. We did not contact all individual maglev interests potentially affected by right-of-way issues nor did we review all possible maglev right-of- way options. Instead, we selected the projects identified to us as being the furthest along in the planning process in order to gain a first-hand view of right-of-way issues and examine the most prevalent right-of-way options.

Although the scope of this report is limited to high-speed maglev technology, several right-of-way issues are common to both maglev and high-speed conventional rail trains (steel wheel on steel rail). These issues include (1) the need to avoid vertical and horizontal curvature in order to maintain high speeds and passenger comfort (although maglev is able to negotiate steeper grades than high-speed conventional rail), (2) the need for total grade separation (especially along high-speed segments of their routes), and (3) the high costs of constructing new track/guideway or upgrading existing track.[7] Where appropriate, we note significant overlapping issues in the report.

We conducted our review between January and October 1991 in accordance with generally accepted government auditing standards. We met with FRA officials to discuss the contents of this report. These officials generally agreed with the contents. As appropriate, we amended the report text to reflect their comments. However, as requested by Senator Reid's office, we did not obtain written agency comments on a draft of this report.

[7]Excerpted from New Ways: Tiltrotor Aircraft and Magnetically Levitated Vehicles, U.S. Office of Technology Assessment (Washington, D.C.: Oct. 1991).

Evaluating Maglev Right-of-way Options

Because a variety of maglev right-of-way options are available, maglev system planners will need to evaluate potential rights-of-way thoroughly. Evaluations will address the suitability of options and will be based on criteria that, taken together, address economic feasibility. Each right-of-way option offers certain advantages and disadvantages with respect to both the construction and operation of maglev systems. In this chapter, we identify criteria for evaluating right-of-way options. We then review several options using these criteria.

Right-of-way Selection Could Affect Economic Feasibility

For most proposed maglev systems, right-of-way acquisition will probably be a long and complex process involving evaluations of individual right-of-way options as well as combinations of options. Although each proposed maglev route will have specific evaluation criteria associated with it, we believe that these criteria generally fall under the headings of technical feasibility, safety, environmental impacts, and legal feasibility. Taken together, these criteria should allow planners to determine whether a maglev system can physically use a particular right-of-way option and whether the system will be economically feasible.

Transportation research literature contains clues as to how right-of-way choice might affect maglev's economic feasibility. For a number of years, DOT has sponsored research on forecasting demand for transportation, including predicting demand for types of services, such as high-speed rail, that do not yet exist. This research has shown that riders choose a transportation option on the basis of several factors, one of which is trip time. Maglev's rapid trip times make it potentially competitive in the medium-distance (150 to 500 miles) travel market, especially when its ability to provide direct service between city centers is taken into account.

To minimize trip time and thus improve the economic potential of a maglev system, right-of-way suitability for high-speed service will be important. For example, maglev systems will require relatively straight and level rights-of-way to maintain high average speeds over a route. Lower speeds could decrease the system's attractiveness to potential riders, reduce potential operating revenue, and jeopardize the maglev system's ability to cover its operating costs and provide a return on investment. However, if the cost of a right-of-way that allows high-speed operations is to be passed on to passengers, it cannot be so great as to raise fares to the extent that travelers choose other transportation options over maglev. Although trip time is important, cost, or the fare, is also significant: In general, research has shown that travelers trade off time and cost. As trip time decreases, travelers' willingness to pay more for the service increases. However, if the fare rises excessively, travelers may seek a less expensive—possibly slower—transportation option.[1]

For travelers, therefore, the cost of high speed cannot outweigh its benefits. As planners design systems and consider right-of-way options, they will need to balance the value of high speeds against the price travelers are willing to pay for high-speed service. Although a right-of-way that allows high-speed operations may be available, planners on a route will need to consider the cost of acquiring that option, how much of that cost will be passed on to riders as fares, and how much potential riders on that route will be willing to pay for faster transportation. Such considerations will help to determine the economic feasibility of maglev route options.

Several Maglev Right-of-way Options Exist

Five basic right-of-way options may be suitable for maglev systems, including (1) existing Interstate and other highway rights-of-way, (2) existing railroad rights-of-way, (3) existing utility rights-of-way, (4) new rights-of-way through public lands, and (5) new rights-of-way through private lands. Each option has advantages and disadvantages. In this section, we assess within the previously described criteria the feasibility of each siting option. Although these evaluations are not exhaustive, they illustrate the issues surrounding the acquisition of maglev rights-of-way.

Interstates and Other Major Highways

Some maglev proponents believe that existing highway rights-of-way offer a readily available and relatively low-cost solution to the right-of-way problem. An extensive network of Interstate highways already exists, and many Interstate rights-of-way contain enough space to accommodate a maglev system either along the highway shoulder or in the median. Furthermore, in some locations, using existing rights-of-way may cause fewer environmental impacts than establishing new routes. Maglev planners, as well as state and federal highway officials, have told us, however, that several economic, technical, and safety issues should be considered before maglev systems are placed within highway rights-of-way.

On the basis of our discussions with highway officials and maglev planners, we believe that determining the overall cost of using Interstate highways for maglev systems will involve complex analyses and will vary with the characteristics of the highway and the maglev system. Right-of-way costs

[1]This is probably true more often with respect to discretionary travelers (e.g., vacationers). Business travelers are generally less sensitive to changes in price.

include two important components: 1) the cost of gaining access to the right-of-way and 2) the cost of conforming the maglev guideway to the highway design. If states provide access to Interstates at no cost, the second consideration will have a greater effect on cost.

Until recently, states were required to charge the fair market value for most nonhighway uses of Interstate rights-of-way. The Congress recently eliminated this requirement, however, when it passed the Intermodal Surface Transportation Efficiency Act of 1991, which allows states to make Interstate highway rights-of-way available without charge to publicly or privately owned entities to build rail and maglev systems. Thus, of all the siting options, Interstates now provide, in many circumstances, the least costly access to land.

The cost of land acquisition is only part of the cost associated with using a right-of-way, however. The cost of conforming a maglev guideway to a highway right-of-way may be substantial because major highways were not designed with maglev systems in mind. Speed and safety considerations are important when designing rights-of-way, and a right-of-way designed for rubber-tired vehicles traveling up to 70 miles per hour may not be optimal for a magnetically levitated vehicle traveling in excess of 250 miles per hour. For example, the minimum curve radii (including both horizontal curvature, or a change in lateral direction, and vertical curvature, or a change in grade) are very different for maglev vehicles and highway vehicles. As table 2.1 shows, maglev vehicles traveling at 250 miles per hour require a horizontal curve radius of 13,700 feet to ensure passenger comfort, while highway vehicles traveling at 70 miles per hour require a curve radius of only 1,910 feet. Although comparable vertical curvature data were not available for highways, highway engineers we talked to told us that automobiles traveling on an Interstate would require a much smaller curve radius than the 82,000 feet required by a maglev traveling at 250 miles per hour.

Table 2.1: Comparison of Ground Transportation Modes' Engineering Requirements

Characteristic	250-mph maglev	300-mph maglev	70-mph freight railroad	70-mph highway
Horizontal curvature (radius in feet)	13,700	21,425	1,910	1,910
Vertical curvature (radius in feet)				
Crest	82,000	126,600	[a]	[a]
Trough	40,500	63,000	[a]	[a]
Gradient (in percent)	Up to 10	Up to 10	Up to 1	Up to 5

Note: Horizontal curvature figures account for each mode's appropriate superelevation, or tilt, when traversing curves.

[a]Comparable vertical curvature data were not available for railroads and highways.

Source: GAO analysis of industry data.

The large differences in design requirements for highways and maglev systems may lead to either or both of the following, each of which would negatively affect the project: 1) the maglev system may sacrifice speed to conform to the highway design and/or 2) the maglev guideway may need to deviate from and/or cross over the highway several times to maintain speed. If the system sacrifices speed to conform to the highway right-of-way, it may not attract enough riders to be economically viable. As previously noted, the number of riders depends, in part, on system speed and the resulting trip time advantage that maglev can achieve over other modes of transportation. Also, frequent deviation from the highway or crossing over the road to maintain speed will raise construction costs. As the width of the highway and the angle at which the guideway will cross increase, the length of the guideway spans will also increase, further adding to cost. Each time the guideway will deviate from the highway, new rights-of-way may have to be acquired, potentially adding to cost.

In addition to curvature restrictions, highway obstacles may also increase the cost of siting a maglev system. The maglev guideway must be high enough to cross over every highway bridge, overpass, and interchange. As the frequency and height of such obstacles increase, construction costs may increase. The entire alignment may need to be raised in order to minimize vertical curves, which affect passenger comfort more than horizontal curves. To minimize the impact of highway obstacles on the California-Nevada system, engineers plan to place the guideway as close as possible to the edge of the right-of-way, where interchanges and bridges are lower and more easily traversed. Nevertheless, the right-of-way is relatively narrow in some places, and highway structures are difficult to avoid. The system may have to deviate from the right-of-way under such circumstances.

In addition to imposing costs on the maglev system, construction of a maglev system within a highway right-of-way may present challenges to those building and managing the highway. For example, the Orlando maglev system is projected to share the right-of-way (collocate) with a proposed toll road for about 2 miles of its route. When the projected use of the toll road was estimated, the impact of the maglev system was not considered. When the maglev system is complete, however, it will attract some riders who would otherwise have driven on the toll road. The existence of the maglev system may decrease revenues on the toll road, and if the shift is significant, it could make it difficult for the toll road authority to pay off the bonds with which the road was financed. If, however, the two projects had been planned together, more reasonable estimates of use could have been reached, and the maglev system might not have been asked to compensate the toll road for lost revenues, as has been requested.

In addition to technical and economic considerations of highway and maglev collocation, highway officials have expressed concerns about the probable safety impacts of collocating a maglev system in a highway right-of-way. The effects of a maglev system on drivers are not well understood. Concerns have been expressed about a possible "startle effect," but there are no data to illustrate the effects of an elevated, 300-mile-per-hour vehicle on drivers. Also, to estimate the effect of vehicle collisions with the guideway, more should be known about the impact that the guideway can withstand. Sufficient clear zones and/or the need for barriers must be determined.

Railroad Rights-of-way

In some locations, existing railroad rights-of-way may offer suitable siting options for maglev systems. Particularly in urban areas where new rights-of-way are difficult and costly to obtain, rail lines may provide a direct route into and out of city centers, as well as into downtown transportation centers to facilitate connections to other modes of travel. Furthermore, as with Interstate highway rights-of-way, using existing railroad rights-of-way may cause fewer environmental impacts in some locations than establishing new routes. The railroads that we contacted were willing to consider railroad and maglev collocation, but they raised several technical, economic, and safety issues that should be considered before placing a maglev system in a railroad right-of-way.

The railroad officials with whom we spoke generally responded favorably to the concept of shared rights-of-way. Several railroads have begun to gain experience in sharing alignments with commuter rail systems, both in situations where the commuter system operates on the same tracks as freight service and where operations are separate. When forming agreements to share an alignment with a commuter system, railroads seem open to a variety of ownership arrangements. A railroad might retain full ownership of the right-of-way and grant an easement to the commuter system. Or a railroad might sell a portion of the alignment to the commuter system and retain an easement over which to operate its freight lines. In another type of arrangement, a railroad might sell its line to the commuter system and abandon or move its freight operations to another line. For any of these options, approval by the Interstate Commerce Commission would be required.

Although railroads are willing to consider right-of-way sharing, representatives of commuter rail systems told us that negotiations with railroads can be costly and time-consuming. For example, railroads have required several transit agencies to pay for engineering modifications to the railroad necessary to allow sharing the right-of-way with a transit system. Such modifications include intrusion detection devices designed to protect both systems from accidental interference by the other. According to officials of one transit system that shares rights-of-way with an active freight railroad, such intrusion protection systems cost about $86,000 per mile. Also, if the maglev system's experiences were comparable to these transit systems' experiences, the maglev system would probably be expected to bear the cost of any necessary changes in railroad track configuration. For one transit agency, the cost of relocating and replacing freight facilities in a 16-mile shared right-of-way was estimated at more than $40 million in 1988.[2] Also, railroads often require commuter systems to carry sufficient liability insurance to cover not only damage caused by the commuter system to the freight railroad but damage caused by the freight railroad to the commuter system as well. As important as the cost is the time involved in negotiating right-of-way sharing arrangements. One transit official told us that negotiations with the railroads could take several years, and therefore planners were required to build substantial lead time into their transit system development plans. Such delays in a maglev project's progress, combined with other costs imposed by railroads, would probably significantly affect the project's costs.

[2] Edward McSpedon, "Building Light Rail Transit in Existing Rail Corridors—Panacea or Nightmare? The Los Angeles Experience." Paper presented at Transportation Research Board - National Conference on Light Rail Transit, May 1988.

Because the railroads wish to protect their economic interests, they would consider the impacts of a maglev system on the efficiency of their freight operations before deciding whether to share land. The railroads need to retain sufficient right-of-way space to maintain their operational capacity and efficiency. This concern is particularly important in the Northeast corridor, where some freight service is already limited to night operations to accommodate passenger trains that run over the same tracks during the day.

The space available for collocation in railroad rights-of-way varies. It depends on the width of the right-of-way and the placement of existing tracks and other entities located in the corridor. In relatively undeveloped areas, rights-of-way may be wide enough to accommodate maglev systems. In heavily developed areas, such as some locations along the Northeast corridor, however, existing rail lines already fill rights-of-way to capacity. Nevertheless, in some cases, it may be possible to accommodate a maglev system by shifting the rail lines to one side of the right-of-way, the cost of which would probably be borne by the maglev system.

Some railroads may also need to retain adequate space for the future electrification of their lines. Railroads in southern California, in particular, will be required to electrify their lines in the coming years to alleviate air pollution problems. These railroads will need adequate space to install the catenary (overhead) wires that will supply them with electric power.

Besides conforming to the space restrictions within a railroad right-of-way, a maglev system would need to operate within an alignment designed for a conventional freight railroad's engineering requirements, which are different from those for maglev. Typically, freight rail beds are designed to minimize inclines (at 1 percent or less) and therefore sometimes traverse relatively tight horizontal curves. As table 2.1 shows, a freight train traveling at 70 miles per hour can traverse a curve radius of 1,910 feet. Maglev, on the other hand, can climb steeper inclines (up to 10 percent) but requires very gentle horizontal curves. A maglev vehicle traveling at 250 miles per hour requires a minimum horizontal curve radius of 13,700 feet. Consequently, maglev systems that stayed within conventional railroad rights-of-way would sacrifice speed in order to traverse the curves. Over long distances, differences in design requirements could impede the economic viability of the maglev system.

In addition to technical considerations, railroads have some concerns about the safety of sharing alignments with maglev systems. If the two systems are too close to one another, a freight train derailment could damage the maglev guideway, thereby endangering passengers and operators on both systems. Also, one railroad representative was concerned about the effects of the guideway on the freight operator's ability to see ahead. The guideway would need to be placed so as not to block the operator's view and jeopardize the safe operation of the freight train.

Finally, some railroads are concerned about the potential interference of maglev's electromagnetic fields (EMF)[3] on railroad signalling and communication equipment. We received a range of responses concerning EMFs from the representatives of major railroads with whom we spoke. Some consider electromagnetic interference (EMI) to be a major concern, and one railroad representative suggested that the Association of American Railroads should study the effects of EMI on railroad equipment. Another railroad representative, however, did not believe that EMI was a serious problem. He stated that any such problems could be solved. In general, railroad representatives expressed interest in obtaining better information about the issue before forming policy on shared rights-of-way with maglev systems.

Generally, maglev and high-speed rail planners have indicated that railroad rights-of-way would be useful to maglev systems for entering and leaving city centers. The proposed Pittsburgh maglev system, although its final alignment has yet to be determined, may collocate with railroad lines leading into downtown Pittsburgh. Similarly, the Texas high-speed rail system, although not a maglev system, has similar right-of-way curvature requirements and plans to collocate with existing rail lines to enter the cities of Houston, Dallas, Fort Worth, and San Antonio. Elsewhere, the Texas system plans to operate mostly on new rights-of-way.

Utility Rights-of-way

Electric utility corridors also offer possible siting options for maglev systems. Such corridors are common and may provide a nearby power source for maglev systems. We obtained comments from representatives of several electric utilities across the country concerning the potential for collocating maglev systems and electric utility lines. While some utility representatives supported shared corridors from a land-use perspective, they indicated that several legal, technical, safety, and environmental issues should be considered before maglev guideways were placed within existing utility rights-of-way.

[3] Electric and magnetic fields are referred to collectively as electromagnetic fields throughout this report.

First, the ownership of utility corridors varies. In some cases, utilities own their rights-of-way. More often, and as is the case for many of the utilities that we contacted, the land is owned by other parties that grant easements to utilities to construct, operate, and maintain their structures over the property. In order for a maglev system to gain access to such rights-of-way, the terms of the easements would need to be changed to include the construction and operation of the maglev system. For those utilities that do rely on easements, maglev planners may have to negotiate with many landowners to gain access. Not unlike establishing new rights-of-way through private land, this process could be time-consuming and costly.

Second, as several utility representatives told us, existing utility corridors are not designed to accommodate the engineering specifications of a maglev system and therefore may not afford optimal siting over long distances. Unlike surface transportation systems, which are bound by limits on curvature and grade, transmission lines can and often do traverse rough terrain and turn at sharp angles (as great as 90 degrees). Representatives of New England utilities, in particular, commented that rough terrain and man-made obstacles in that part of the country produce power line corridors that take very sharp turns, thereby decreasing these corridors' compatibility with ground transportation systems.

Third, existing utility rights-of-way may not contain enough extra space to accommodate a maglev system, either in terms of present or future utility operations. In terms of present capacity, the lines may not be constructed to provide adequate clearance for a maglev system to operate in the same corridor. To accommodate maglev systems safely, utility lines might need to be raised, reconfigured, or buried to provide adequate clearances. For example, a utility official in New York State said that utility corridors there were generally not wide enough to accommodate rail facilities safely. In terms of future capacity, utilities wish to retain enough space to meet future needs. One utility representative in Massachusetts commented that new rights-of-way were almost unobtainable and, therefore, utilities hoped to meet future transmission needs by fully utilizing existing rights-of-way.

Finally, representatives of many of the electric utilities that we contacted raised a recent environmental issue—electromagnetic fields (EMF). EMFs are present wherever there is electricity, including near power lines and maglev systems. Exposure to EMFs is thought to be linked to certain forms of cancer, although the evidence is inconclusive. As public concern over EMF exposure grows and information about actual EMF effects remains vague, electric utilities are reluctant to compound the EMFs associated with their transmission lines with those from other sources. Given that the scientific community has yet to reach a consensus on the health effects of EMF exposure and the federal and state governments have yet to agree on whether and how to regulate exposure, utilities wish to remain flexible. One utility representative stated that it may not be in the best interest of utilities or of the public to site high technology entities within utility corridors; utilities need to retain a buffer zone to meet existing or future EMF regulations.

The Orlando maglev project, which plans to collocate with electric utility lines for about 4 miles of its 13.5-mile route, is negotiating with the Orlando Utilities Commission, which is concerned about maintaining its flexibility with respect to EMFs. Beyond a certain distance (within which EMF levels are relatively constant), EMF levels decrease with distance away from electricity transmission lines. The state of Florida has set regulations for the EMF levels permissible at the edge of a transmission line right-of-way. Currently, the Orlando Utilities Commission meets the regulation within its existing 135-foot right-of-way. The right-of-way includes a buffer zone, or enough land to meet more stringent regulations should the state enact them. However, if the utility were to shift its lines and allow the maglev system to use 35 feet of its right-of-way, the utility would have a smaller buffer zone and might not be able to meet more stringent standards. Also, if the lines were moved to accommodate the maglev system, they would be located closer to a residential area, which might concern area residents. To resolve these concerns, the lines might be buried—an option that would cost about $4 million per mile and would be paid for by the maglev system.

Although there are challenges to siting a maglev system in a utility corridor, there are also advantages, according to the Orlando maglev planners. This particular utility corridor's straight geometry affords the only opportunity for the system to reach its planned top speed of 250 miles per hour. Over the remainder of the system's alignment, curves dictate a speed of less than 250 miles per hour, or an average system speed over the route of about 125 miles per hour. Therefore, access to the utility corridor or adjacent land is important for the demonstration potential of the Orlando system.

Although utilities are concerned about the compatibility of existing rights-of-way and maglev systems, some have expressed interest in joining together with surface transportation planners to design new rights-of-way that would be compatible with both interests. They believe that new corridors, designed jointly, could be engineered to avoid problems with clearances, EMFs, and other concerns generated by existing alignments. Some of the utilities we contacted are finding it increasingly difficult to establish new rights-of-way and are interested in the potential for joint-use corridors.

New Rights-of-way Through Public or Private Lands

In areas where existing rights-of-way are neither available nor compatible with maglev systems, new alignments may be the only option. New rights-of-way offer advantages over existing rights-of-way in terms of technical feasibility, safety, and, in some situations, cost. New alignments may, however, offer challenges in terms of environmental impacts and legal procedures.

An important advantage of new rights-of-way is that engineers can design an alignment that best meets maglev's curvature requirements. Numerous maglev planners and engineers have told us that existing rights-of-way, including highway, railroad, and utility corridors, would limit curve radii, thereby limiting maglev's speeds. New rights-of-way could be constructed to accommodate the curvature requirements of maglev vehicles operating at high speeds. By using a right-of-way that allows maglev to fulfill its potential, developers could minimize total project costs.

Total project costs include the initial costs of acquiring land and constructing guideways, as well as the costs of operating the system. Although some observers believe that existing rights-of-way offer a more economical siting option than new land, others argue that land acquisition costs have been exaggerated and that the operational advantages of using new rights-of-way outweigh any added acquisition costs.

The cost of acquiring private land for new rights-of-way will probably be more expensive than the cost of gaining access to existing rights-of-way, particularly if access to Interstate highways is available at no charge. Land becomes increasingly expensive as a system nears urban areas, where it may be more economical to use railroad or other existing rights-of-way.

In contrast, the cost of using rights-of-way through public lands is relatively inexpensive. According to the Bureau of Land Management's 1991 rental schedule for linear rights-of-way, a maglev system could pay less than $20 per year per mile of right-of-way space (assuming a 60-foot right-of-way) through Clark County, Nevada, through which the proposed

California-Nevada system would travel. In San Bernardino County, California, the system could pay about $75 per mile per year for use of a right-of-way through public land. Such rental rates represent nominal costs to a system that may cost several billion dollars to construct.

Some maglev planners told us that the cost of land acquisition, even if private lands were used, would be relatively minor compared to overall project costs. Those planning the Orlando maglev system, which would be built on both public and private lands, estimate that right-of-way costs will account for only about 5 percent of total project costs, or about $30 million of the projected $600-million total.

New rights-of-way could mean lower engineering and construction costs. With a new alignment, the guideway can be placed so as to minimize the obstacles that must be traversed. Also, whereas the use of highway rights-of-way over long distances might necessitate weaving back and forth over lanes of traffic, a new right-of-way could minimize interaction between the maglev system and other transportation routes, such as highways and railroads tracks. A new right-of-way would thus contain construction costs by limiting the need for extra-long guideway span lengths.

In addition to potentially containing construction costs, new rights-of-way designed for high speeds may allow maglev systems to earn the revenues necessary to cover operating costs. As discussed in the beginning of this chapter, research has shown that riders base their choice of transportation options, in part, on trip time. A new right-of-way, designed to accommodate maglev's high speeds, could minimize trip time, thereby encouraging ridership. As the number of riders on a particular system increases, so, too, do the system's chances of covering operating costs.

A route designed specifically for a maglev system could also avoid some of the safety concerns associated with shared corridors. The route could be designed to minimize interaction between the maglev system and other entities, thereby decreasing the chances of highway or railroad vehicles colliding with the guideway. Also, given sufficient clear zones between the maglev guideway and other entities, the maglev system's EMFs would be less likely to interfere with nearby electronic equipment.

In terms of environmental impacts, constructing a guideway in a new right-of-way might impose greater costs than constructing a guideway in an existing right-of-way. Construction in a new right-of-way, particularly through a previously undeveloped area, might disrupt important wildlife habitats. The proposed California-Nevada maglev system would be built within the habitat of the desert tortoise, a threatened species, and near the habitats of other protected species of animals and plants. The planners will need to consult with the Bureau of Land Management and the U.S. Fish and Wildlife Service to obtain permission to cross such areas and to minimize impacts. Once construction is complete, however, a maglev system on an elevated guideway may interfere less than other rail systems with animal habitats because the guideway allows wildlife to pass underneath. Thus, the system's impact may not be substantial during operation. However, questions remain about the impact of noise and vibrations on the surrounding area.

Because of the negotiations required to obtain new rights-of-way, this option may be the most time-consuming, particularly if the system requires large amounts of private land. There may be many landowners with whom to negotiate. The states of Texas and Florida are facilitating the acquisition of private land by granting powers of eminent domain—the right of government to take private property—to their high-speed rail entities. However, if many landowners are involved, it could take years to condemn or purchase the land. Those planning the Orlando system have spent several years gaining access to about one half of the parcels of land they will need to build the 13.5-mile route. The Florida Department of Transportation may assist by acquiring some of the remaining parcels by eminent domain.

Conclusions

Existing transportation and utility rights-of-way are prevalent throughout the country and offer, to varying extents, potential siting options for maglev routes. Interstate highway routes are readily available and may present the lowest acquisition costs of any option. Railroad rights-of-way are among the most practicable siting options for entering and exiting congested urban areas. Utility rights-of-way are advantageous for maglev systems because they afford access to power sources. However, none of these options is wholly compatible with the special engineering requirements of high-speed maglev systems. Most would, in fact, require major modifications to the existing entities within the right-of-way or to the maglev guideway components in order to be compatible with maglev operations. Most of these modifications would probably be performed at the expense of the maglev system and would therefore add to the system's cost of using existing rights-of-way. However, using existing rights-of-way without modifications would probably reduce maglev's speed and performance, thus limiting the system's economic attractiveness. When these modification costs are taken into account, existing rights-of-way become less attractive for maglev routes. We believe that emphasizing maglev construction within one type of right-of-way, particularly an existing right-of-way, may be overly restrictive and undermine the competitiveness of such systems.

Although existing rights-of-way currently have drawbacks that limit their usefulness for maglev routes, future advances in maglev technology may make these rights-of-way more desirable. For example, maglev vehicles are being designed with tilt mechanisms that would allow operations with much smaller curve radii than the current technology can use. This research may eventually lead to maglev designs that will make high-speed operations in existing highway, railroad, and utility rights-of-way feasible.

With existing technologies, however, most maglev systems will probably need new rights-of-way for portions of their routes to maintain high speeds. Acquiring new rights-of-way may be more expensive than using existing corridors, but maglev guideways in new rights-of-way can be designed to meet maglev's curvature requirements, thus allowing the vehicles to maintain high speeds while meeting passenger comfort requirements. Therefore, a new, custom-designed right-of-way could maximize the number of riders and bolster the system's chances of financial success. However, because of environmental and community concerns, acquiring new rights-of-way may, in many cases, be more time-consuming and legally complex than accessing existing rights-of-way.

As we discussed in chapter 1, a strategy to facilitate the siting of maglev systems could be developed to identify and preserve in advance corridors that could accommodate high speed ground transportation, as well as potentially accommodate other uses, including highways and utilities. Regional, state, or local officials could preserve corridors by obtaining control of, or otherwise protecting, the right-of-way for a planned transportation and/or utility facility. The preservation of transportation corridors could be an important component of maglev planning by allowing for orderly assessments of impacts; orderly project development; minimization of environmental, social, and economic impacts; and reduced costs.

Maglev Projects Face Challenges to Acquiring Rights-of-way

In order to gain a first-hand view of maglev right-of-way issues, problems, and possible solutions, we selected and visited the sites of three proposed maglev projects. These are (1) the Anaheim, California, to Las Vegas, Nevada, Super Speed Train project, (2) the Orlando, Florida, International Airport to the Orlando International Drive maglev demonstration project, and (3) the downtown Pittsburgh, Pennsylvania, to the Greater Pittsburgh International Airport maglev demonstration project. Each has received federal funding or research support from federal agencies. In this chapter, we describe the projects and examine right-of-way issues germane to each.

California-Nevada Maglev Project

A planned Transrapid maglev system between Anaheim, California, and Las Vegas, Nevada, would transport passengers over the approximately 270-mile distance in about 75 minutes. Traveling at an average speed exceeding 200 miles per hour, the maglev would significantly decrease surface travel time between the two cities. Existing ground transportation options between Anaheim and Las Vegas include driving on major highways (about a 5-hour trip) and riding on the one Amtrak train that operates daily (about a 7-hour trip). Trip time via maglev would be competitive with air travel between the two cities, which currently takes about an hour (not counting the time it takes to get to and from the airport).

In addition to saving travel time, the maglev would conserve energy and promote economic development, according to proponents of the system. Planners estimate that the system would reduce petroleum-based energy consumption in the Southern California-Las Vegas Corridor by about 17 percent. Also, an estimated 25,000 new, permanent jobs would be created as a result of maglev operation between Anaheim and Las Vegas, and $600 million in new earnings would be added to each state's economy.

System Status

In August 1990, the California-Nevada Super Speed Train Commission awarded a franchise to construct and operate a high-speed maglev system from Anaheim to Las Vegas. The winning franchisee, led by the Bechtel Corporation, originally planned to have an operational system by 1997 or 1998. On November 4, 1991, however, Bechtel withdrew as franchisee of the California-Nevada project for two reasons: 1) because of changes in the world financial market, Bechtel was unable to secure sufficient development capital for the project and 2) the governor of California vetoed legislation that would have extended the funding for California's Super Speed Train Commission. (The Nevada Super Speed Train Commission is still intact.) The project has not been abandoned, however.

The members of the California commission plan to reorganize and seek reauthorization again. If reauthorization is granted, the combined California-Nevada Commission may issue a new request for proposals.

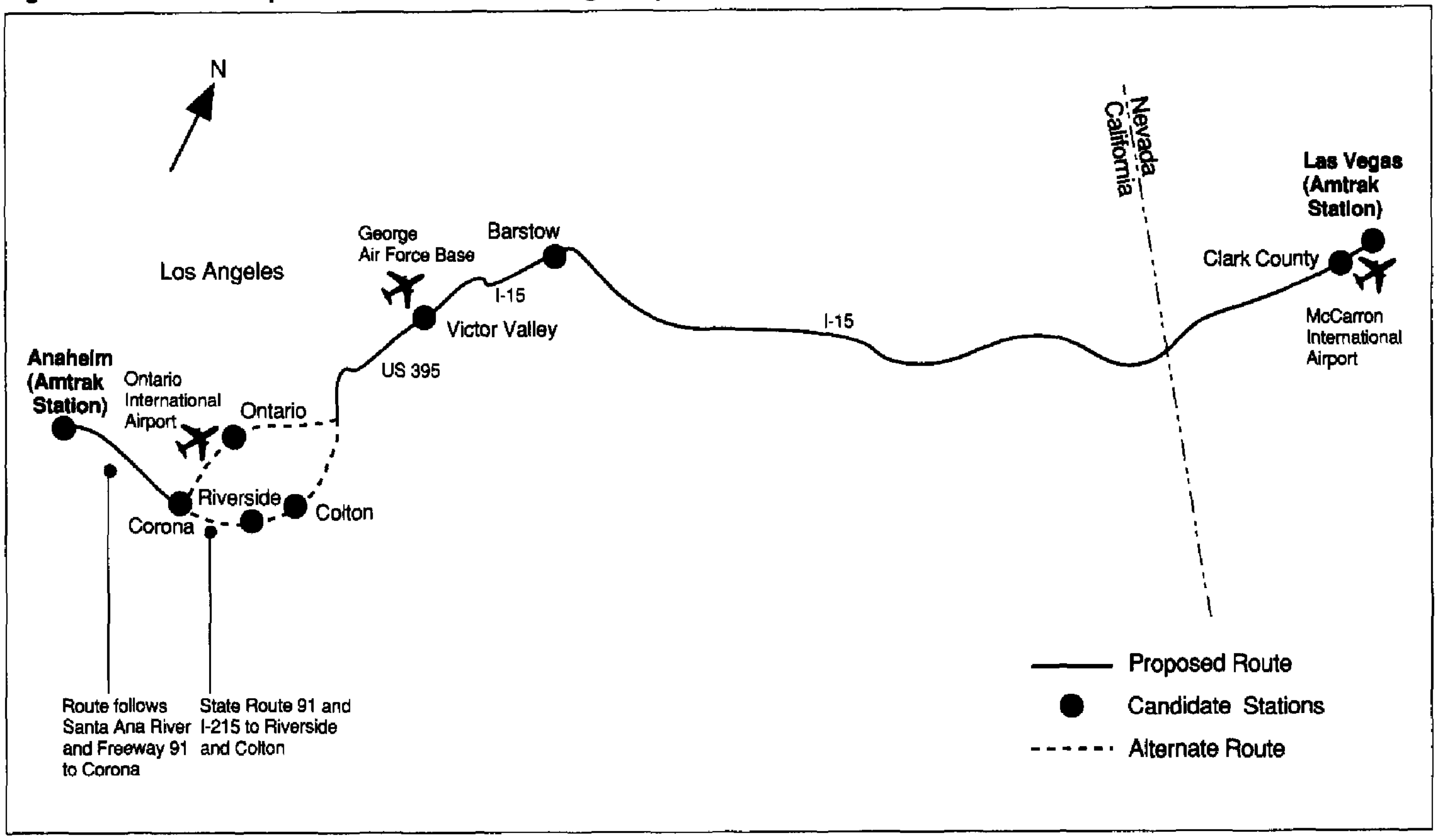
System Costs and Financing

Bechtel estimated that the project would cost about $5.1 billion to construct. All construction funding was expected to be private, but the project benefited from two FRA grants. In 1983, FRA granted the city of Las Vegas $1.5 million for five maglev studies that led to the proposal for the California-Nevada system. In June 1990, FRA granted the California-Nevada Super Speed Train Commission $250,000 for evaluating potential franchisees to build the system.

Proposed Alignment

Maglev terminals would be located near Anaheim Stadium and, in Las Vegas, either downtown or near the airport. Depending on the final alignment, the system would make five or six intermediate station stops, most of which would be west of Barstow, California (see fig. 3.1). The maglev system would employ a double track guideway, about 50 percent of which would be constructed near ground level, with the remainder on elevated concrete columns of varying height.

Figure 3.1: Route of Proposed California-Nevada Maglev System



Source: Bechtel Corporation.

Over most of the alignment, Bechtel proposed to collocate the maglev system with Interstate 15, which connects southern California to Las Vegas. The maglev guideway would be constructed within the shoulder of the highway, which would present challenges to engineers. In the more developed areas near the west end of the route, highway shoulders are very narrow and cannot accommodate a maglev guideway (see fig. 3.2). Also, in some areas the highway curvature will not allow a maglev system to maintain high speeds. Where space is insufficient or curves are too restrictive, the guideway would deviate from the highway to maintain speed.

Figure 3.2: Proposed California-Nevada Maglev Route Showing Section of California Route 215 Right-of-way, San Bernardino

Where the maglev system would deviate from Interstate 15, new rights-of-way might need to be established through federal lands within the California Desert Conservation Area. The Desert Conservation Area was established to protect the fragile desert environment while accommodating multiple uses of the land. New rights-of-way would be established through consultation with the Bureau of Land Management, the U.S. Fish and Wildlife Service, and the state agencies responsible for protecting the desert ecosystem. Of particular concern would be the maglev system's impacts on the habitats of threatened or endangered species. For example, as noted in chapter 2, the system would pass through habitat of the desert tortoise, which the Fish and Wildlife Service has listed as a threatened species. Planners would need to consult with the Fish and Wildlife Service to determine appropriate methods of protecting the habitat.

In addition to Interstate and new rights-of-way, the system might collocate with some existing railroad rights-of-way, especially leading into Las Vegas and into Barstow, California. In Barstow, the railroad tracks lead to an old railroad station that could be rehabilitated to serve as a maglev station. The Santa Fe Railroad also has a maintenance yard there that could accommodate a maglev maintenance yard.

The maglev guideway could also be placed in flood control channels that run parallel to the Interstate over part of the alignment, although the effects of this option have not been thoroughly studied. Bechtel's project manager told us that, structurally, the guideway could be built safely in the flood control channel. Its construction, however, could disrupt the flow of the flood control system by placing obstacles in the channel.

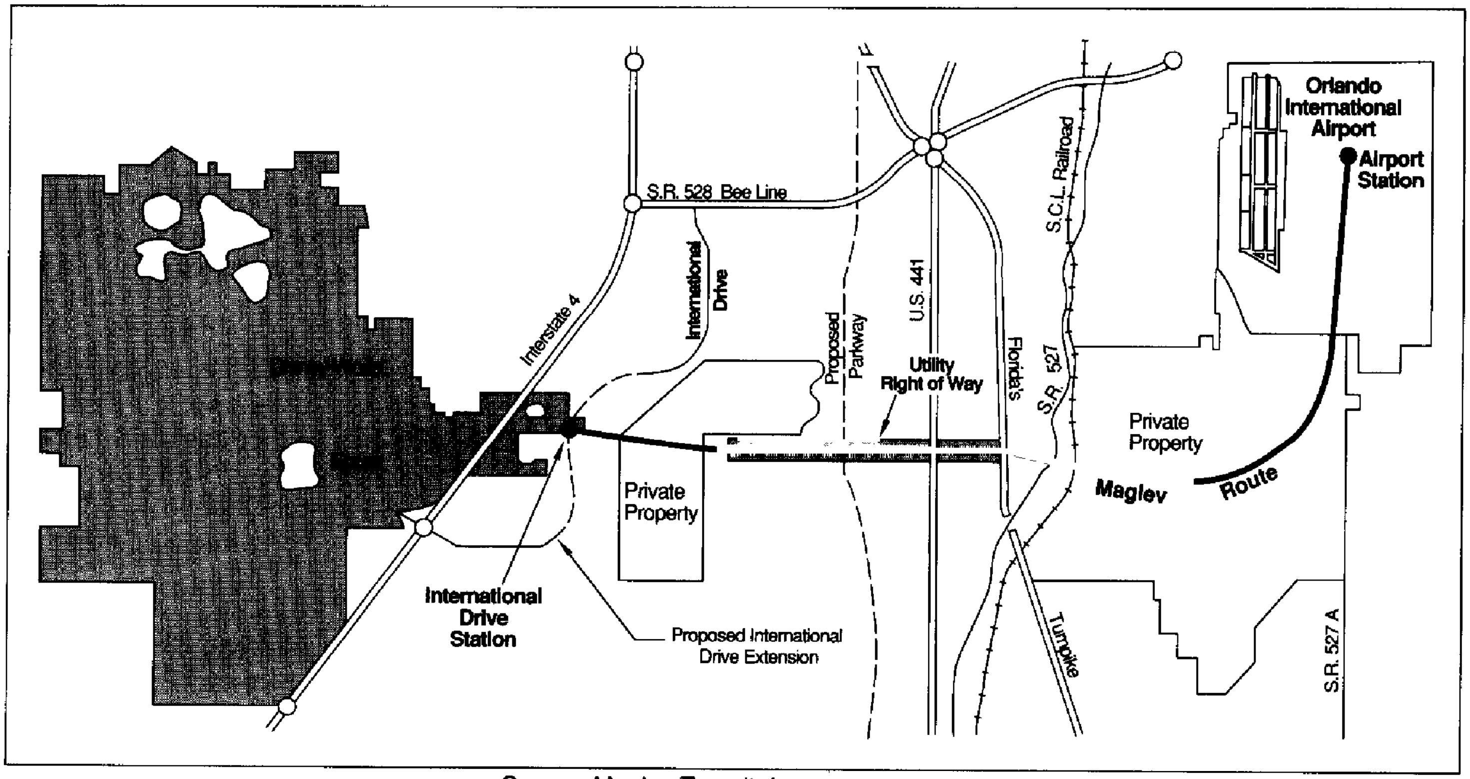
Special challenges to this system include the geotechnical and seismic conditions present in California. Because the system would traverse active or potentially active faults, its foundation must be constructed to withstand earthquakes. Engineers plan to make use of experience gained by the U.S. Geological Survey in monitoring seismic activity, as well as experience gained by the Japanese in operating the Shinkansen, or Bullet Train, through seismically active areas.

Orlando Maglev Demonstration Project

A Transrapid maglev system planned for Orlando, Florida, would carry visitors 13.5 miles from Orlando International Airport to a location in the vicinity of hotels and attractions (see fig. 3.3). Maglev vehicles would reach a top speed of 250 miles per hour and traverse the route in about 6.5 minutes, cutting travel time by about 75 percent. Ground transportation from the airport is currently provided by taxis and rental cars, which take 25 to 30 minutes to cover the same distance.

Although the route is relatively short, those planning the Orlando system believe that their experience will provide valuable information for others planning to build and operate maglev systems in the United States. They believe that the Orlando system will demonstrate the ability of a maglev to serve an airport. They also believe that it will test the constraints associated with collocation, since the system is projected to share rights-of-way with electric utility lines and a toll road. Finally, the Orlando system will provide empirical data on transferring the German Transrapid technology to American uses, particularly with respect to safety.

Figure 3.3: Route of Proposed Orlando Maglev Demonstration Project



Source: Maglev Transit, Inc.

System Status

On June 12, 1991, Florida's governor granted certification to Maglev Transit, Inc. (MTI), to build the Orlando maglev system. Certification allows the project to take advantage of coordinated construction permitting. Currently, MTI is working to meet the certification conditions that must be fulfilled before the start of construction. MTI plans to break ground for the maglev guideway in the fall of 1992. Construction should be complete in mid-1995, and operation should begin in the fall of 1995.

System Costs and Financing

Total cost is estimated at about $600 million, of which about 5 percent is attributed to right-of-way costs. The system is projected to be privately financed. MTI expects the project to be financed by a consortium of Japanese, German, and American companies.

Proposed Alignment

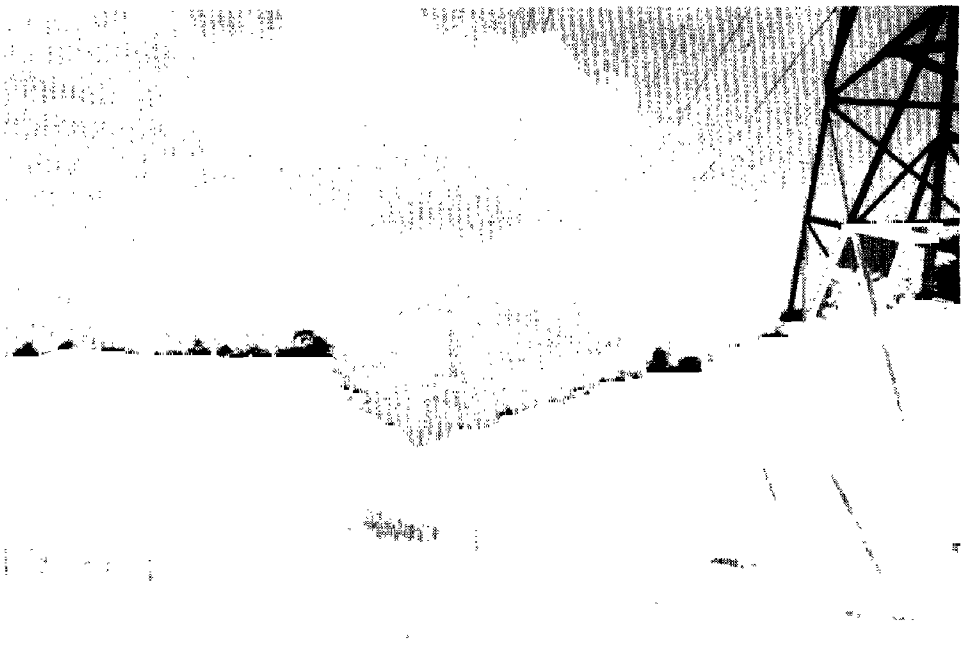
MTI is assembling the maglev right-of-way through the following means: (1) about 4 miles of the alignment would fall on airport land; (2) over another 4 miles, the maglev system would collocate with the Orlando Utilities Commission's electric transmission lines; (3) over about 2 miles, the maglev would collocate with the Southern Connector Expressway, a planned toll road being designed and built by the Orlando-Orange County Expressway Authority; and (4) the remaining land has been or will be acquired from several individual landowners. The state Department of Transportation may exercise its powers of eminent domain to obtain access to some of the remaining land.

The major challenge on airport property will be to route the maglev system under the taxiway. Although a tunnel runs under the taxiway, it is reserved for light rail and heavy rail lines, which, although neither has yet been built, were part of the airport's master plan before the maglev system was planned. MTI is discussing its options with the Greater Orlando Aviation Authority, including the feasibility of building another tunnel under the taxiway.

According to MTI, only in the transmission line corridor will the maglev system attain its top speed (250 miles per hour). This corridor is very straight over the approximately 4 miles where the maglev system plans to collocate (see fig. 3.4). In order to accommodate the maglev system, however, the transmission lines will have to be reconfigured or buried at MTI's expense. Also, because the Orlando Utilities Commission does not own the corridor but has an easement, MTI will need to obtain access from several private landowners, which will increase the difficulty of acquiring land.

Along the proposed toll road right-of-way, it is uncertain whether the maglev system will parallel the Southern Connector Expressway in two locations or whether the system will cross over the road and back again in the two locations. MTI and the expressway authority (whose design for the toll road is complete) disagree over the design of the road (which is scheduled to open in 1993) and the maglev guideway. MTI claims that the expressway authority did not take the maglev plans into account when designing the road. The expressway authority claims that MTI did not provide them with accurate information about the placement of the maglev system. The result is that the highway's geometry may not be suitable for maglev collocation. In order to maintain speed, the maglev system may have to cross the road rather than parallel it, which could increase construction costs.

Figure 3.4: Proposed Orlando Maglev Project Route Showing Orlando Utilities Transmission Corridor



In addition to raising design concerns, the expressway authority has also been concerned about the maglev system's effects on toll revenues. The authority asked the maglev system to compensate it for lost revenues. The Florida Department of Transportation granted the authority's request because the maglev system was jeopardizing the authority's ability to sell bonds for the toll road. As a result, the maglev system will be required to compensate the expressway authority for the passenger tolls that the toll road would otherwise have generated.

For the project to gain access to some of the remaining parcels of land, MTI expects that the Florida Department of Transportation will need to use its powers of eminent domain. Where necessary, the Department would condemn the land, compensate the landowners, and lease the land to the maglev system. Some of the land would then be controlled by MTI and some by the state. To avoid complications arising from mixed ownership, MTI may sell its portion of the corridor to the state, which would then lease the land to MTI. The details of such an arrangement have yet to be worked out.

The most significant environmental concern affecting maglev construction in the Orlando area is the need to preserve wetlands. The maglev system, as planned, would cause the loss of 14 acres of wetlands, which would be mitigated at the rate of 30 to 1—that is, for every acre of wetlands lost, the maglev system would acquire and preserve 30 acres of wetlands elsewhere in the area.

Pittsburgh High-Speed Maglev Demonstration Project

In Pittsburgh, a high-speed maglev system connecting downtown Pittsburgh with a new midfield terminal at the Greater Pittsburgh International Airport is currently under study. This approximately 19-mile route would also be built using Germany's Transrapid maglev technology and would be the first leg of an extensive proposed intra- and interstate maglev system. The system would cut travel time between the airport and downtown to about 10 minutes from the current 45 to 60 minutes.

In addition to saving travel time, maglev proponents hope that the Pittsburgh system will be the beginning of a Pittsburgh-based national maglev industry. A consortium of businesses in the Pittsburgh area hopes to establish a maglev industrial base, creating new jobs while making use of existing industrial resources.

System Status

"Maglev, Inc.," a consortium of private, public, and academic organizations, is developing this project. The project is currently in its "Design-Development-Demonstration" phase, which includes expansion of preliminary studies in a number of areas, such as alignment options, environmental impact, and financing. Some of these studies are still under way.

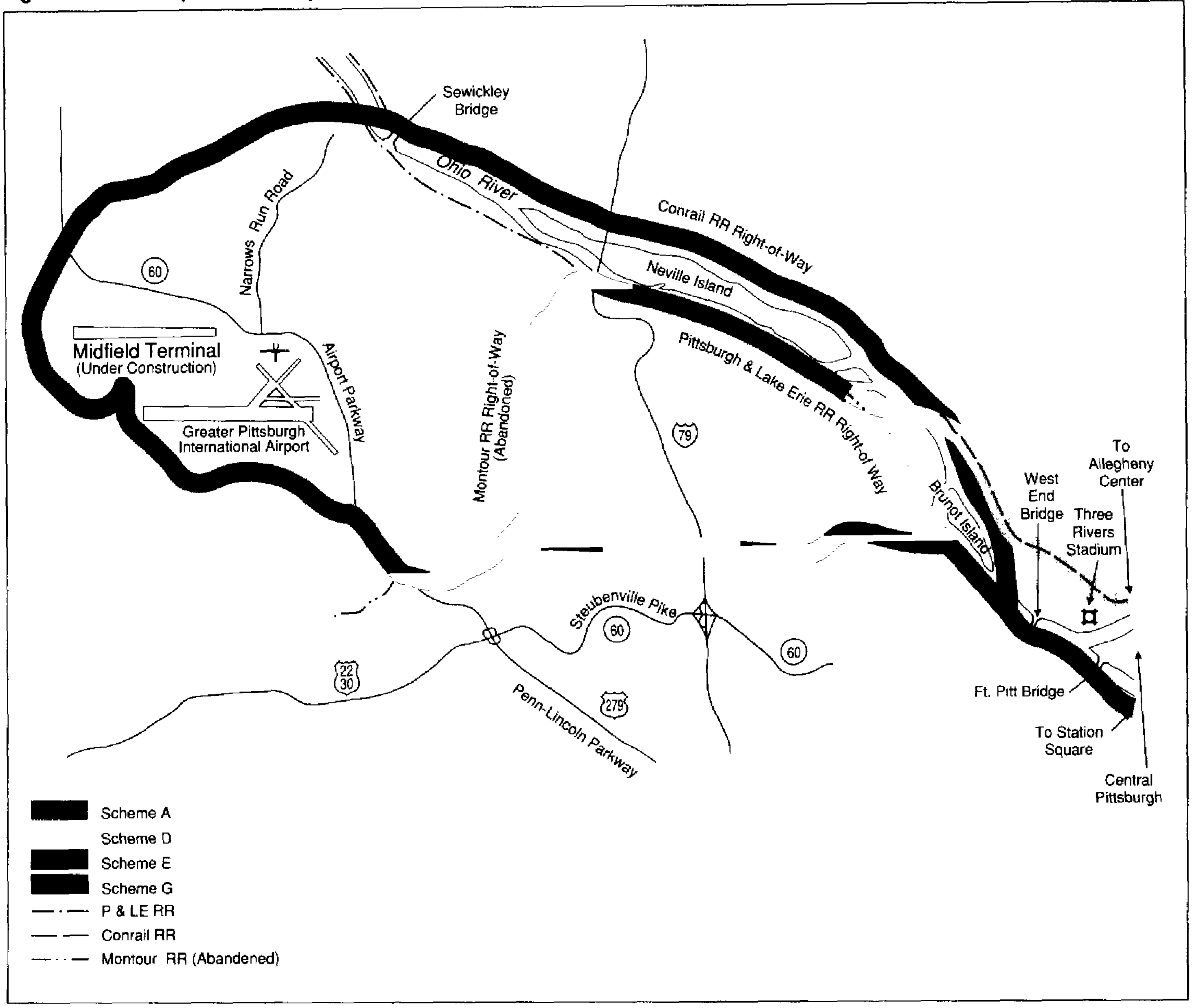
System Costs and Financing

The Pittsburgh demonstration project, using a single guideway alignment, is estimated to cost between $460 million and $530 million. The estimates for project right-of-way acquisition range from $8 million to $24 million, depending on the length of the right-of-way and whether it is acquired through easements or purchased outright. In April 1991, the Urban Mass Transportation Administration granted $660,000 to Maglev, Inc., through the Port Authority of Allegheny County (Pittsburgh), a member of the consortium, to study the proposal.

Proposed Alignment

The Pittsburgh maglev project's designers are examining four alternative alignment schemes for the system, as shown in figure 3.5. Each alignment begins at a new midfield terminal at the Greater Pittsburgh International Airport and ends in one of several possible sites in downtown Pittsburgh.

Figure 3.5: Route Options for Proposed Pittsburgh Maglev Demonstration Project

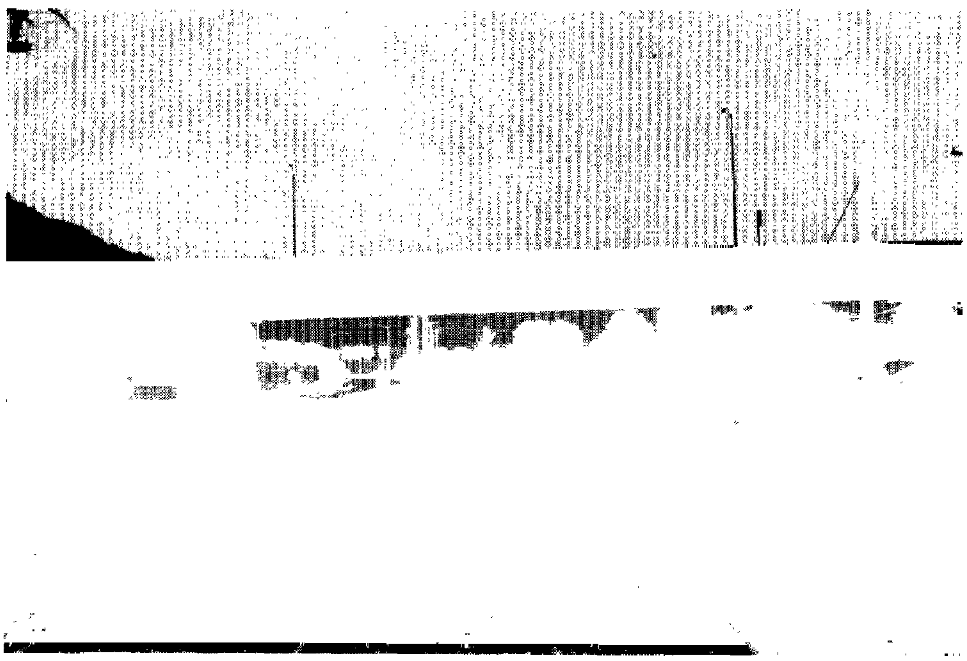


Source. Maglev, Inc. (Baker Engineers).

All alignment schemes for the Pittsburgh project would use a combination of new and existing rights-of-way. Significant right-of-way acquisition issues include the need to share existing rights-of-way with railroads and to work around the hilly topography of the Pittsburgh area.

All of the alternative alignment schemes developed by Maglev, Inc., for the demonstration project would share rights-of-way, at least in part, with railroads (see fig. 3.6). Maglev, Inc., officials told us that initial analyses of the costs and legal issues associated with using railroad rights-of-way have been performed, but, as of November 1991, no significant work had been done in this area.

Figure 3.6: Proposed Pittsburgh Maglev Project Route "Scheme G" Showing Conrail Railroad Right-of-way on North Shore of Ohio River

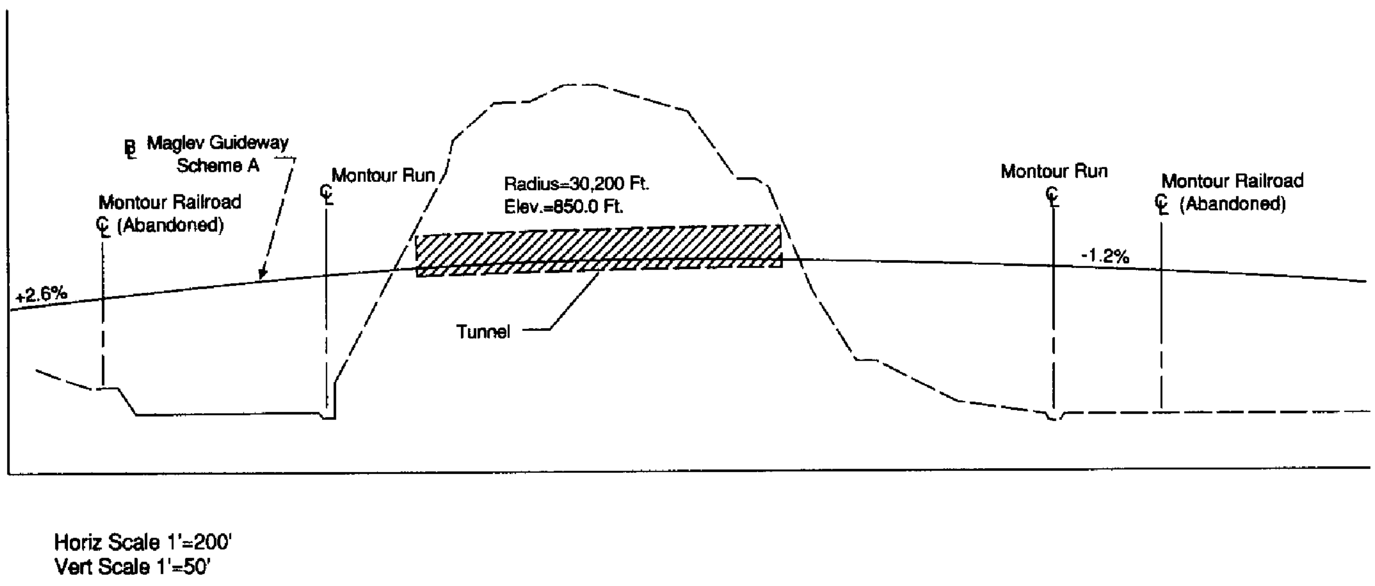


"Scheme G," which Maglev, Inc., has designed to run mainly along the north side of the Ohio River, would use much of an active railroad right-of-way. Maglev, Inc., officials told us that this right-of-way is generally very wide and would allow the maglev line room for curves. However, the right-of-way still has numerous small curves that could force the maglev line to swing outside the railroad right-of-way in several places to maintain a high speed.

One of the major issues affecting the project's feasibility is the topography of the land available for rights-of-way. The Pittsburgh metropolitan area is situated in a very hilly region of western Pennsylvania. We were told that the terrain actually will dictate where the maglev right-of-way will be located. Although the system's planners will attempt to follow highways, railroads, and valleys to the extent possible, even a relatively low system design speed of 150 miles per hour will necessitate mainly new rights-of-way. Maglev, Inc., officials told us that existing rights-of-way and valleys generally have curve radii and gradient transitions too severe for high-speed maglev operations.

Because of the hilly terrain and the incompatibility of many of the existing rights-of-way through the hills, Maglev, Inc., officials anticipate that they may have to build tunnels for the maglev guideway in the vicinity of the airport (see fig. 3.7 for an example of a tunnel cross section). This engineering challenge could add significantly to the system's cost. National Maglev Initiative officials told us that FRA wants to learn more about safety issues associated with maglev operation in tunnels. They also stated that maglev systems will require a large tunnel cross section to accommodate the displacement of air in the tunnel. Similarly, Maglev, Inc., officials said that relatively little is known about maglev operation in tunnels. These officials expressed concern about the effects of air pressure differentials as a high- speed maglev vehicle enters or exits a tunnel and about resultant safety problems. These questions will require resolution before construction of the project can begin. Some answers could eventually come from Japan, where a 40-kilometer maglev test track now under construction will be in tunnels for about 80 percent of its length.

Figure 3.7: Cross Section of Topography on Pittsburgh Maglev Project Alignment "Scheme A"



Note: See figure 3.5 for the location of Scheme A.

Source: Maglev, Inc. (Baker Engineers).

Guideway construction within tunnels, compared to normal guideway construction outside of tunnels, will also be costly. According to maglev researchers, because of the relatively large tunnel cross section required for high-speed operations, constructing a maglev system in a tunnel may cost three times as much as constructing an elevated system or about four or five times as much as constructing an at-grade system. Researchers estimate that a maglev tunnel could cost about $30 million per mile to construct. For the Pittsburgh demonstration project, Maglev, Inc., initially estimated that tunnelling could represent from 1.6 percent to as much as 6.7 percent of project construction costs, using unit cost estimates of $6,400 per linear foot.

Conclusions

The three projects that we examined—California-Nevada, Orlando, and Pittsburgh—illustrate the challenges that maglev developers face in acquiring rights-of-way. While all of these projects face some similar siting obstacles, each also faces challenges unique to its location. The California-Nevada project must conform the maglev system to the existing Interstate right-of-way to the extent possible and, where necessary, develop new, environmentally sound rights-of-way through a fragile desert area. In Orlando, the maglev system must collocate with other transportation and utility entities in developed areas. The Pittsburgh project's planners must deal with the topography of the project route as well as arrange to share rights-of-way with active railroad lines. These are not the only right-of-way acquisition challenges these projects face, but they illustrate the location-specific nature of right-of-way issues. Information sharing could assist maglev project planners in dealing with these complex issues, enabling them to learn from the experience of others. This effort could be made at the federal level to help system planners better understand and manage obstacles to right-of-way access and thus facilitate the establishment of maglev systems as well as of other high-speed ground transportation systems that share some right-of-way issues.

Local planners and developers may be best qualified to address the challenges of siting a specific system; therefore, actions taken at the federal level that preserve flexibility will help to facilitate right-of-way acquisition and accommodate the site-specific requirements of different projects. For example, those designing the California-Nevada maglev system were depending on the availability of Interstate rights-of-way at little or no cost. This expectation may now be realistic, following passage of P.L. 102-240, which allows states to make Interstate rights-of-way available without charge to publicly or privately owned entities to build rail and maglev systems. Projects such as those planned for Orlando and Pittsburgh, however, would not directly benefit from actions facilitating access to Interstate highway rights-of-way. At least in the short term, these two projects are relatively limited and local in scope, and their right-of-way needs will be met primarily by access to local, state, or privately owned land. If plans to expand the Pittsburgh system are realized, then federal actions to facilitate Interstate access may prove beneficial.

Recommendation

We recommend that the Secretary of Transportation direct the Department, as part of the National Maglev Initiative, to establish a central clearinghouse for information collected on rights-of-way for high-speed ground transportation systems. This information, particularly that based on actual experience, should be made available to system planners through mechanisms such as newsletters, conferences, and transportation research centers.

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