U.S. Passenger Rail Technologies

December 1983

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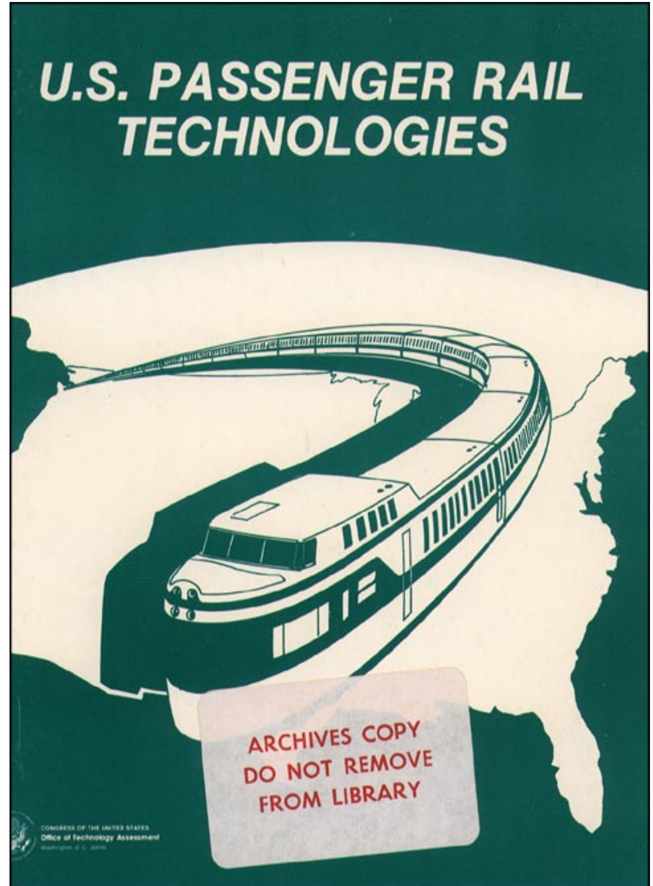

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Foreword

Passenger rail transportation has been the subject of much concern and congressional action for the past two decades in the United States. As the country's transportation system evolved to include increased use of air and automobile technologies for intercity travel, passenger rail service experienced significant ridership declines, resulting in institutional changes from private to public sector operation.

For the decade of the *IWO'S,* Federal attention focused primarily on determining and stabilizing a core passenger rail system for the country. While history reflects that the United States, since the early 1960's, has been interested in high-speed rail and advanced ground transport technologies, including magnetic levitation, the more pressing societal issues of a failing rail infrastructure and institutional reform have taken precedence in the policymaking arena for the past decade. Thus, expertise in high-speed rail now rests primarily abroad.

At this juncture, however, discussion related to growth and change in passenger rail technology, particularly high-speed rail and magnetic levitation, is increasing. Nine corridors are being actively explored by State and local governments, regional agencies, and U.S. and foreign technology developers and suppliers for possible application of high-speed ground transport systems.

This OTA assessment seeks to lay out in general form what is known about these high-speed technologies and the foreign experience with them. It also seeks to identify the areas of uncertainty relative to their application in the United States. The study is intended to identify significant policy questions and issues that will be pertinent to Federal, State, and local debate on this subject.

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OVERVIEW

High-speed passenger rail systems (125 mph and above) now operate in Japan, France, and Great Britain. There is growing interest in introducing such passenger rail service in this country, and several State and local governments and private sector groups recently have undertaken feasibility studies for this purpose. Prompted by these initiatives, the Subcommittee on Transportation of the House Committee on Appropriations; the Senate Committee on Commerce, Science, and Transportation; and the House Committee on Energy and Commerce asked the Office of Technology Assessment (OTA) to examine the experience of foreign countries and to assess the outlook for high-speed passenger rail technology in the United States. As part of this study, OTA also was asked to examine the prospects of magnetic levitation (maglev) technologies—ultra-high-speed ground transportation that relies on magnetic suspension instead of conventional steel wheels on rail—and the status of railcar manufacturing industries.

High-speed rail.—The technologies for high-speed rail are well understood. High-speed rail systems are costly to construct, and all foreign high-speed lines have been built with government assistance. They generally report favorable financial results, with regard to operating costs, though independent audits to confirm this are not available.

The lowest cost option, typically used for lower volume operations, is conventional diesel-powered equipment on existing track, the system the British have in operation. The most expensive option is to build new track, which the Japanese have done. The cost of building new track, although higher than upgrading existing track, varies widely depending on terrain, land use, and population density. For example, although the new French high-speed line cost $4 million per mile to construct, the most recently completed two links of the Japanese system cost an estimated $35 million to $40 million per mile. The original route cost about $20 million per mile. *

High-speed systems require high ridership to generate enough revenue to cover operating costs. The high-speed rail systems of Europe and Japan are situated in corridors that have higher population densities than any of those being considered in the United States, with the exception of the Washington, New York, Boston Corridor (the Northeast Corridor or NEC). Also, both Japan and France had reached capacity on sections of their conventional lines before implementing high-speed service.

OTA's analysis of the factors that influence a passenger's choice of travel mode suggests that a potential high-speed passenger rail corridor should have some or all of the following characteristics: 1. cities grouped along a route giving major passenger travel flows in the 100- to 300-mile-trip range; 2. cities with high population and high population densities; 3. cities with developed local transit systems to feed the high-speed line; and 4. a strong travel affinity (reason to travel) between cities, generally because one city is a dominant center of commercial, cultural, or governmental activity.

OTA did not evaluate specific proposals for high-speed corridors in the United States. Based on foreign experience and current U.S. market factors, however, it seems that *any U.S. corridor with totally newhigh-speed rail service would have difficulty generating sufficient revenues to pay entirely for operating and capital costs.* This same comment does not necessarily apply to upgraded rail lines or other improvements.

Maglev technologies. -Different types of maglev systems for high-speed intercity passenger service are being developed independently by the Federal Republic of Germany and by Japan. Although neither system appears to have insurmountable technical obstacles, both require further development and testing to substantiate technical feasibility and to determine the capital and operating costs under conditions that fairly reflect those of actual revenue service. Not

***Per-mile costs for the Japanese lines are shown in 1979 dollars.**

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until 1985 will sufficient information be available from the West German tests to determine if the system can meet performance standards under operating conditions at costs suitable for revenue service. Japan is seeking to build a new test track and continue testing the advanced technology developments, including the superconducting magnets used in their system.

Railcar manufacturing.—As a result of adverse market conditions, all U.S.-owned passenger railcar manufacturers have abandoned the field. * U.S. sales are being filled by foreign owners. U.S. manufacturers (other than the Budd Co.) are not likely to reenter the field unless the United States follows the example of Europe and Japan, which sustain their passenger railcar manufacturing industries by ensuring a stable, predictable, and planned market for rail equipment. At present, the U.S. market for railcars is small and uncertain. Most railcar orders for the rest of the 1980's already have been placed, and the market for the 1990's and beyond is not likely to be large enough to support more than a few small U.S. manufacturers.

* The Budd Co., though located in the United States and employing U.S. labor, was purchased by Thyssen, a West German corporation, in 1978.

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SUMMARY

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Chapter 1
SUMMARY

At the request of the Subcommittee on Transportation of the House Committee on Appropriations, the Senate Committee on Commerce, Science and Transportation, and the House Committee on Energy and Commerce, OTA examined five questions concerning high-speed rail and magnetic levitation (maglev) passenger technology, and railcar manufacturing:*

1. What is the status of high-speed rail technologies and passenger service abroad?
2. What activities are underway to bring such technologies and service to the United States?
3. What is the outlook and what are the implications of introducing high-speed passenger rail systems in the United States?
4. What is the status of maglev technologies?
5. What is the status and outlook for the U.S. passenger railcar manufacturing industry?

The information for this assessment was obtained through analysis of technical literature, supplemented by interviews and workshops with experts in the field of passenger rail technology.** OTA did not evaluate the economic feasibility of any individual corridor proposal. However, based on foreign experience and analysis of market factors likely to affect rail ridership, OTA did draw some general conclusions regarding high-speed rail application in the United States. The following is a discussion of these conclusions.

*For purposes of this study high-speed rail was defined as systems with maximum design speeds of 125 mph and above. Chapters 2, 3, 4, 5, and 6 focus on technology, economic and institutional considerations pertinent to intercity transportation. The focus of *Chapter 7: U.S. Passenger Railcar Manufacturing* includes manufacture of intercity, commuter, and urban transit railcars.

**A complete bibliography of literature reviewed for this study is available from the OTA Science, Transportation, and Innovation Program Office.

MAJOR FINDINGS

High-Speed Passenger Rail Systems and Technologies

Foreign Experience

The development of high-speed passenger rail technologies has taken place almost entirely in France, Great Britain, and Japan. These countries consistently have placed a high priority on passenger rail service as a matter of explicit national policy and have developed extensive passenger rail networks that are, in varying degrees, government subsidized. Development of rail systems with improved speed is underway in other countries as well, though not studied in this report.

The Japanese, in the mid-1960's, were the first to introduce regular high-speed passenger rail service with the Shinkansen, or "bullet train, " service between Tokyo and Osaka. That line, and the later high-speed extension between Tokyo and Hakata, are the only dedicated high-speed lines in the world to have earned a profit and repaid capital investment costs. In the mid-1970's, the British began to introduce high-speed rail service on existing, upgraded routes throughout their national system. In 1981, the initial segment of the new French high-speed line between Paris and Lyon—the TGV—began operation, with service over the entire line scheduled for 1983. The French are confident of profitability and the British achieve a satisfactory return, repaying all but 10 to 15 percent of operating and capital costs.

The Three Foreign Systems

The three foreign high-speed systems differ significantly; each is tailored to its particular topography, transport needs, demographic conditions, and economic circumstances.

Japan .-The Japanese chose to construct entirely new track and equipment, because they had no alternative. The existing narrow gage rail lines were unsuitable for high-speed service and heavily overloaded with traffic. There was a fully developed transit feeder system. The early bullet trains attracted a large ridership—85 million on the Tokyo-Osaka line in 1970. Ridership for the entire Shinkansen system in 1980 was approximately 125 million.

Great Britain.—The British, concerned that their existing passenger rail network increasingly would lose riders to competing travel modes, decided in the early 1970's to introduce high-speed service. They considered the construction of an entirely new high-speed railway, but rejected it on the grounds of projected high costs and probable environmental opposition. Instead they chose to employ conventional technology and designed trains with maximum speeds of 125 mph that could share existing track with freight and commuter trains.

France.—To ease severe congestion on the Paris-Lyon line, the French chose to build a new high-speed line to divert a major part of the intercity passenger train traffic away from that area. The new high-speed track runs through sparsely populated country between Paris and Lyon, where the line connects with existing track on the outskirts of the two cities. Because the new system was designed to traverse steep grades (avoiding the expense of tunneling) and sparsely populated areas, the construction costs reportedly have been low. In just over a year, the French have carried 5.6 million riders on the Paris-Lyon run and expect to attract *16* million riders annually when the network is completed. The French Government has also encouraged TGV travel by restricting intercity bus travel along highway routes.

Photo credits: TGV America

SNCF Train a Grande Vitesse (TGV) first class car (interior view). Maximum seating of 111 passengers in first class, 275 passengers for second class

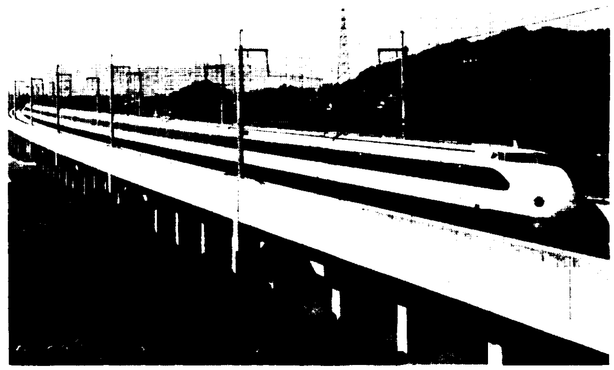

Photo credit: Japanese National Railways

Shinkansen, "Bullet Train," on elevated guideway

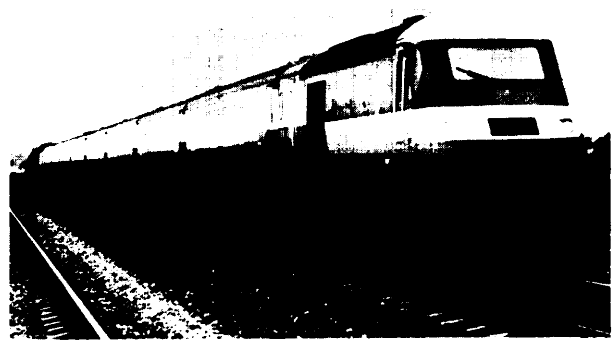

Photo credit: TRANSMARK

British Rail High Speed Train

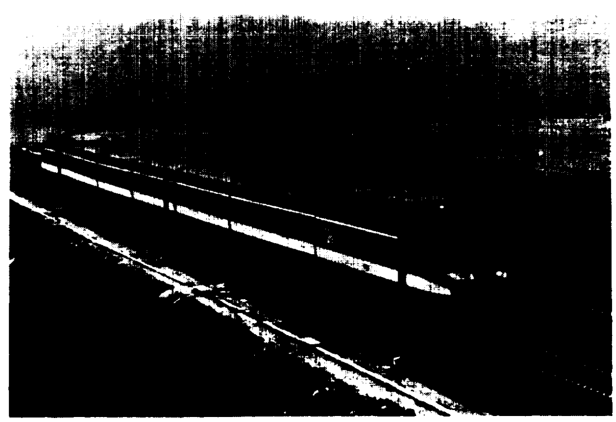

Photo credit: TGV America

SNCF Train a Grande Vitesse

U.S. Activity

In the United States, a number of private and State-sponsored initiatives to introduce either high-speed rail or maglev are at different stages of planning—notably in California, Florida, Michigan, New York, Vermont, Nevada, Wisconsin, Ohio, Pennsylvania, and Texas. In addition, a Midwest Rail Compact of States interested in high-speed rail has been formed to investigate a possible five-State network. These efforts are being promoted, in part, by U.S. and foreign firms that might undertake corridor development or supply the technology. Some advocates of these ventures have suggested some form of Federal assistance will be needed, while others claim none or very little will be required.

Technology Options

The basic technology options for high-speed rail service include combinations of equipment, track, and propulsion systems. All equipment and track options and several of the propulsion options are in use or under development abroad.

Equipment and Track Options.—

- *Improved conventional equipment on upgraded existing track (Great Britain).* This */east-cost option* uses conventional equipment at a maximum speed of 125 mph on existing track, shared to some degree with freight and/or commuter trains. (The Northeast Corridor (NEC) now is operating trains at speeds up to 120 mph on certain segments of the corridor.)
- *Advanced technology on existing track (Great Britain, Canada).* Great Britain and Canada as well as others are developing different versions of a "tilt-body" train that can provide improved schedules on existing track, because of its ability to take curves at higher speeds than conventional trains. However, technical problems with the tilt-body equipment make transforming prototype equipment into an attractive commercial operation difficult.
- New *equipment, part new track, or totally new track (France, Japan).* For its new TGV high-speed service between Paris and Lyon, France uses state-of-the-art equipment on existing track into and out of Paris and Lyon, and on new track between the two cities. The amount of new track constructed, the terrain, and the population density determine the costliness of this option. Japan used state-of-the-art equipment on totally new track, including access to cities, for its Shinkansen service because the original narrow gage track was not suitable for new high-speed trains.
- *Very high-speed new modes beyond steel wheel on rail—maglev (West 'Germany,* Japan). Japan and West Germany currently are conducting development work on maglev systems, which are capable of speeds in excess of 250 mph. The West German system is being tested under conditions and at performance levels that the West Germans believe are necessary to prove revenue service application. The Japanese also are conducting further test and development; their systems employ more new technology than the West German system. The United States terminated its maglev research program in the mid-1970's.

Propulsion Systems.—The propulsion system options include *diesel power, electric power (including linear synchronous motors),* and *gas turbinepower.* Gas turbine power has been virtually abandoned due to poor fuel efficiency. Linear synchronous motors are being developed for high-speed maglev systems. Only electric and diesel power are suitable for state-of-the-art high-speed rail systems. Diesel power is cheaper and more flexible than electric power for low-volume operations; however, electric power can provide improved acceleration, higher speeds, and better braking. It is less expensive than diesel for high-density operations, and in the long term maybe preferred over dependence on liquid fuel.

Comparison of Options.-The cheapest capital costs for high-speed service result from diesel-powered conventional equipment on existing track at a maximum speed of 125 mph. A high-density operation is required before the economies offered by electric power can overcome the high fixed-capital costs associated with electric catenary and transformers. The most expensive option is to use electrically powered high-speed trains on completely new track at speeds well in excess of

125 mph. The costs of building new track, although always higher than upgrading existing track, can vary significantly from one place to another. The costs of the system depend on such factors as location, terrain, length of route, right-of-way issues, the high-speed technology selected, and the service levels to be provided. The construction cost of the French TGV line, for example, was reported to be $4 million per mile. The two latest sections of the Japanese Shinkansen are estimated to have cost about $35 million to *$40* million per mile, principally because of the extensive tunneling and viaducts required in Japan. The earlier Shinkansen lines cost approximately *$20* million per mile in 1979 dollars. The upgrading costs for the NEC have ranged between $4.5 million and $5 million per mile with an additional $2.5 million per mile for electrification. *

Minimum Characteristics of High-Speed Corridors

High-speed passenger rail systems require high ridership to generate enough revenue to cover most or all of operating costs, let alone capital costs. Thus, all existing foreign high-speed rail services have been introduced on corridors serving major population centers.

Analysis of the factors that influence the passenger's choice of travel mode, and of the experience of foreign high-speed systems, suggests that before a corridor is considered for high-speed passenger rail service, it should have some or all of the following minimum characteristics:

- cities grouped along a route giving major passenger travel flows in the 100- to 300-mile trip range;
- cities with high population and high population densities;
- cities with developed local transit systems to feed the high-speed rail line; and
- a strong "travel affinity" (reason to travel) between cities, generally because one city is a dominant center of commercial, cultural, financial, governmental, or other activity.

High population and high population densities are probably the most important characteristics of a potential high-speed rail corridor because they make possible the ridership levels and the support for the local transit infrastructure required for successful high-speed service.

Methods of measurement vary slightly, but, with few exceptions, U.S. cities have lower population densities than cities in either Europe or Japan with high-speed rail service. Table 1 shows 1980 population and population densities for selected European, Japanese, and U.S. cities. The data used in the table is for center city populations and excludes outlying suburban areas.

Based on foreign experience and current U.S. market factors, it appears that any U.S. corridor with totally new high-speed rail service would have difficulty generating sufficient revenues to pay entirely for operating and capital costs. Introduction of high-speed rail service, therefore, well may depend on whether the public benefits are judged sufficient to justify public support.

Maglev: Status and Outlook

Two different maglev technologies capable of speeds 250 mph and above are being developed abroad for high-speed intercity passenger service.

Table 1.—Population and Population Densities in Europe, Japan, and the United States

City pairs	Population (000s)	Square miles	Density (population per square mile)
Paris	8,548	827	10,300
Lyon	1,171	279	4,200
Tokyo	11,649	357	32,800
Osaka	2,648	98	27,100
London	6,900	621	11,100
Glasgow	763	61	12,447
New York	7,072	302	23,500
Washington	638	63	10,200
Chicago	3,005	228	13,174
Detroit	1,203	136	8,874
Los Angeles	2,967	468	6,400
San Diego	876	320	2,700

SOURCE: "Far East and Australia Statistics," 19S182, Europa Publications; "U.K. Statistical Yearbook, 19S1, by HMSO (Her Majesty's Statistics Office); "Whittaker's Almanac," 1963; "19S0 Census of Population," U.S. Department of Commerce, PC80 Series, February 1982.

* Costs include system design, program management, and construction, according to Department of Transportation officials.

The attraction maglev technology, which employs conventional iron-core electromagnets, is being developed by the Federal Republic of Germany. The repulsion maglev technology, which employs superconducting magnets, is being developed by Japan.

Both systems rely on electromagnetic forces to provide support (levitation), lateral guidance, propulsion, and braking without direct physical contact between the vehicle and the guideway. To date, neither system has been tested and operated at speeds and conditions necessary to determine if it can perform to desired standards at costs that will justify actual revenue service. The West German system is now in the final developmental testing stage. The results of the tests are expected in late 1985. The Japanese system is still in the experimental stage, and plans for a new test track are being considered.

Although capital costs can be estimated, the reliability of current guideway cost projections has been questioned by some because of the extremely close guideway/vehicle tolerances required in constructing a maglev system. Operating costs cannot be determined accurately until testing has occurred, though theoretical operating estimates are available.

West German and Japanese developers and other potential suppliers of maglev technologies are discussing with a few U.S. State and local governments the possibility of testing or eventually introducing maglev systems. According to a feasibility study prepared by technology suppliers for a Las Vegas-Los Angeles route, Federal support is not required to build a maglev route, although the feasibility study assumes that right-of-way would be made available at little or no cost by the Federal and State Governments. The feasibility study provides a joint public-private sector financing plan, in recognition of the risk involved in implementing the new technology. Additional feasibility studies for this corridor are being conducted by the Department of Transportation.

U.S. Passenger Rail Manufacturing Industry

Status and Outlook

There is currently no U.S.-owned passenger railcar manufacturer. * U.S. manufacturers are not likely to decide to reenter the market and manufacture railcars unless the U.S. Government (like other major Western countries and Japan) assures a stable, predictable, and planned rail equipment market that spreads orders out more or less evenly and in manageable sizes. Other factors likely to influence U.S. industry reentry into the railcar market are continued standardization of railcar requirements for the various passenger rail systems in this country, and continued improvements in some local procurement requirements.

Few U.S. passenger car orders are expected for the rest of this decade. For the 1990's, the total average annual railcar construction orders in the United States are estimated to be between 450 and 550 cars—possibly large enough, under the right conditions, to support a few small U.S. manufacturers. The addition of a new high-speed rail corridor would not significantly alter the overall market picture for railcar manufacturing.

Today, purchases by New York City and Chicago together represent about 77 percent of the total U.S. transit market and more than 40 percent of the total U.S. railcar market with six different railcar designs. Their plans for fleet replacement or expansion are the most important factors in determining the size and nature of the railcar market in this country. Amtrak now has a largely new fleet, and replacement needs for the next decade are likely to be small.

* The Budd Co., though located in the United States and employing U.S. labor, was purchased by Thyssen, a West German corporation, in 1978. U.S. passenger rail manufacturing refers to intercity, commuter, and transit cars.

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Questions for Public Policy

Interest in high-speed rail development in the United States dates to the early 1960's when Congress began examining passenger rail along the Northeast Corridor (NEC) and when the Government began exploring ways of retaining intercity passenger rail service. The basic policy questions considered at that time—including economic viability, corridor suitability, and technology options—still apply. However, today the available technologies (particularly equipment) are more advanced and typically are provided by foreign suppliers. The demographic characteristics of some U.S. corridors also have undergone some change during the last two decades.

Recent proposals for high-speed rail and maglev corridor development have tended to focus on private sector development or some form of public-private sector cooperative enterprise. However undertaken, any high-speed corridor developed will affect substantially a region's structure, environment, and total transportation system as well as pose fundamental questions of public policy at all levels of government. These include:

- what anticipated public benefits are to be derived from introducing high-speed or maglev service?
- what are the anticipated public costs?
- if the benefits of implementing such a system are judged sufficient, what funding will be necessary, and who should pay for implementation of the service?

Some benefits of high-speed systems are quantifiable. Others are a matter of societal and political judgment. Similarly, some costs, particularly those associated with economic efficiency of the system, can be projected; others are more difficult to estimate. As discussed in the following section, some claimed benefits, when taken individually, appear small. However, when all benefits, tangible and intangible, are taken into account, a given region or locality may well wish to implement a high-speed system. Benefits and costs, however, must be examined for the near-term as well as long-term impacts.

PUBLIC BENEFITS AND COSTS

The public benefits often cited for high-speed rail service include:

- increased transport system capacity and mobility;
- reduced congestion in highway and airport ground traffic and other environmental gains;
- energy efficiency, economic development, and employment; and
- safety.

In addition to these explicit reasons, national pride and a desire for continued and modern rail service are also reasons that appear to influence public opinion in favor of high-speed services. "If other countries can provide such service successfully, then why can't the United States?" is a question frequently raised.

Possible public costs of a high-speed passenger rail system include near- and long-term subsidy of the system if ridership and revenues are insufficient; environmental concerns; adverse effects on competing travel modes, services, and employment; and questions of regional equity.

Following is a discussion of the potential benefits, costs, and tradeoffs that may influence decisionmaking regarding high-speed rail.

Benefits

Several types of benefits potentially occur from introduction of high-speed transport systems: some result from long-term improved transport system capacity (high ridership) and mobility; others from system implementation irrespective of improved capacity and the resulting ridership. The latter benefits typically have more near-term impacts, whereas the benefits resulting from improved capacity have longer term implications for the region involved.

The large ridership capacity inherent in a high-speed system allows for new travel demand, for accommodation of population growth of a region, and provides for a competitive alternative to divert some travelers from other modes. To illustrate the ridership levels that can be achieved by frequent high-speed service, the original Tokyo-Osaka line attracted 85 million riders in 1970. Five years later, the total line, extending from Tokyo to Hakata, attracted a high ridership of 157 million passengers. Assuming that high ridership volumes result, other potential benefits that could stem from the improved transport system capacity include reduced energy consumption, regional economic development (including tourism) and resulting employment, reduced air traffic and highway congestion, and improved transportation safety.

Analysis of available data suggests that rail is an energy-efficient mode only in high-volume corridors. Like other individual means of conserving energy, it should not be overlooked, but, by itself, it will make only a small contribution on high density routes. One proposal for a high-speed passenger rail corridor in Florida views the advantage of the system not as a means of saving energy, but as a means of shifting some transportation to a reliance on electricity, thus backing up Florida's ability to attract and care for tourists in the event of another oil shortage and to provide mobility for the State's citizens. Changes in the future availability and cost of transportation energy may alter the perspective on transportation needs and high-speed rail applications in the United States.

Regional economic growth, including tourism and real estate development and the resulting employment, also are benefits that may result from the improved capacity offered by implementation of high-speed rail. The newness of maglev technologies in particular is thought by its advocates to be a major stimulus of new travel demand in corridors where it is being proposed.

More transportation options would result from the introduction of high-speed rail. There is little evidence provided to indicate that it will significantly affect highway and airport congestion. The former generally is caused by commuter and other urban area access traffic rather than intercity traffic. Hence, those benefits of a high-speed rail system inferred from its ability to relieve highway congestion need careful analysis, as does the relationship of commuter services and fares to the overall system design. Whether a high-speed system will relieve airport ground congestion depends, again, on the individual corridor. With the possible exception of NEC and southern California, it does not appear that high-speed rail service would have an appreciable effect on airport ground congestion. Much of the activity for other large airports that now have or are soon to have severe congestion results from passenger flight transfers. High-speed rail would not alleviate this.

With regard to safety, high-speed rail systems have fared well. The record of the Japanese Shinkansen system essentially is perfect. There have been no passenger fatalities on that system since it became operational in 1964. The British system, even though it operates shared facilities with commuter and freight rail, is considered to have a good record as well. The new French TGV reports no passenger fatalities for its operation to date. If new technology for high-speed passenger rail is introduced in this country, several issues associated with safety standards and practices will require consideration and review. In addition, operational and safety certification of these new technologies also will be required. Potential maglev developers already are beginning to investigate U.S. certification procedures.

One safety issue of concern for the United States will be that of protection for rail/highway grade crossings. While it is less costly to provide warning signals and gates at grade crossings (as is done in rural areas of Europe) than grade separation, grade crossing accidents in the United States account for the highest fatality category in rail safety. According to some State officials, rural populations probably will seek to ensure that grade separations are provided if a high-speed rail route is to be implemented in their area, and grade separation—an expensive step—could well be mandatory.

Regulatory standards for track currently included in the Federal Code also will have to be reexamined. U.S. practices for building railcar equipment could be inadequate as well. Countries that have high-speed services have found it necessary to modify vehicle construction methods in the interest of ride quality, weight reduction, and fuel economy. There appears to be no evidence that these changes have reduced the safety of the vehicles, and both the French and the British agree that features of the designs would make them safer in a collision than the conventional equipment. U.S. construction is such that a U.S. vehicle of a given capacity weighs more than those now built abroad, adversely affecting fuel consumption. If high-speed rail is introduced in the United States, equipment specifications may need to be reviewed and the issues of track shared with the heavier U.S. freight equipment will need to be addressed. U.S. track standards also would need revision to permit higher speed operations.

The potential benefits described above are based on near capacity ridership. OTA's review of foreign experience and U.S. market conditions suggests that if ridership sufficient to justify system implementation is to be attracted, the following characteristics of a corridor are necessary: cities with major passenger travel flows of 100- to 300-mile trip range; cities with high populations and high population densities; a strong travel affinity (reason to travel) between cities; and cities with developed transit systems to feed the rail link. *At these distances and with these conditions, assuming frequent service and effective fare policies, rail can compete with air and automobile transportation. For shorter distances, rail will only compete where special circumstances exist. For longer distances air is likely to dominate the market.* Predicting the level of travel resulting from the introduction of high-speed systems is difficult; and is the most uncertain factor in the decision-making process.

Other benefits will result from high-speed rail systems including employment during construction of the rail system itself. As discussed in chapter 7 of this report, foreign firms now have an exclusive hold on the U.S. railcar market, though one foreign-owned firm located in the United States employs U.S. labor. Rail system employment is dependent on service frequency, labor agreements, and degree of system automation. Construction employment would be corridor specific.

costs

There are likely to be public costs associated with the provision of any high-speed passenger rail system in the United States. The market for intercity passenger rail has been eroded steadily by air travel and automobiles. If rail is to attract the ridership necessary to help meet operating costs, it must compete with other transport modes both private and public. If it does not compete effectively, public assistance for operating expenses may become necessary. Some argue that the loss of ridership and consequent service losses from other modes, were high-speed rail to be successful, should be considered a public cost, particularly if the new rail service receives some Government support. A recent Congressional Budget Office study concludes that rail receives much higher Federal subsidies than any other intercity passenger mode, although rail proponents disagree with this analysis.

A second public cost maybe that of capital subsidy, whether directly for the construction, or indirectly, as the associated costs of building public facilities (e.g., parking) to support the rail system, or those required for relocation or redesign of existing public facilities. As indicated elsewhere in this report, every high-speed system in the world initially has received some form of Government support. If some rail corridors are undertaken as private sector, State and local ventures, Federal Government assistance may eventually be sought to complete such projects, if construction timetables and costs are not met as planned. Additional support may be required if original market and cost forecasts are inaccurate.

An interesting institutional question arises regarding Amtrak, the congressionally designated passenger rail carrier in the United States. Amtrak negotiates agreements with freight carriers for use of their rights-of-way in all but NEC and a few other segments. The fact that several high-speed passenger rail corridors may be developed as privately operated enterprises raises questions of the effect of such new service on existing Amtrak service and on the provisions of services Amtrak may offer to such an enterprise. Amtrak could compete with the new rail service on the same corridor, or it could drop service if it could not make an adequate percentage of its operating revenues from that line, In the latter instance it might also be reimbursed by private sector operators for lost revenues resulting from the new service, as is now planned in an agreement between Amtrak and the American High Speed Rail Corp. Legal questions have been raised about whether Amtrak's licensing authority extends to all passenger services in this country, or whether it is confined to routes and corridors on which Amtrak currently provides service.

Another issue related to costs is the question of regional equity. Since there are a number of corridors currently being reviewed for possible introduction of high-speed passenger rail or maglev service introduction, and from all indications some Government support appears necessary, then questions of the equity of Government support among regions of the country becomes an issue. Which, if any, corridors should receive support? What criteria should be used to evaluate such support?

Finally, the potential environmental impact of noise has tended to be a critical issue associated with high-speed rail introduction. The Japanese high-speed system encountered initial strong opposition due to the noise and vibrational effects generated by the passing trains. These effects later were mitigated by technical and social adjustments. Noise levels of foreign systems fall within U.S. Government standards. Maglev systems are reported to be environmentally preferable in terms of noise. Tests to verify this are included in the West German test plans.

Congressional Role

Independent of specific consideration of technology or corridor decisions on high-speed rail, it is important to rethink the fundamental role to be played by rail in a changing transportation network. The present rail infrastructure in the United States is essentially the remaining core of a past system. Other nations have developed the high-speed rail technologies as a means of transforming their rail systems. Accordingly, Congress may wish to encourage further research on transportation systems of the future and to formulate guidelines for the contributions that could be made to them by differing technologies.

There are a number of uncertainties associated with U.S. development of high-speed rail. The technologies themselves are the least uncertain; they can be made to work. Decisions on location, number of stops, and frequency of service will contribute strongly to the attractiveness of the system; these decisions, appropriately reflecting local political and social concerns, cannot be predicted. Costs of construction and operation, while likely to exceed initial projections, can probably be forecast to some acceptable certainty. By far the most uncertain factor is the issue of ridership over time. Realizing very large ridership projections now being made will require a major change in current U.S. transportation patterns.

If Federal assistance is required for development of U.S. high-speed corridors, questions of competing transportation priorities, regional equity among corridors, likely public benefit, and economic success, will confront policymakers. Most of the estimated long-term benefits and costs depend on the accuracy of ridership projections and the effect of such ridership on other transportation modes. The gains that occur irrespective of the ridership tend to be more near term, accruing to those involved in building the system.

In light of these facts, if Congress should decide to support the development of high-speed passenger rail, several activities warrant consideration:

- Detailed independent evaluations of those corridors with high-speed rail potential are needed to assess carefully the benefits and costs of introduction of a high-speed passenger rail system. The evaluations should include:
  - —range of potential ridership and factors affecting it;
  - —probable costs (including those due to mishaps or delays) and certainty of cost forecasts;
  - —magnitude of regional support;
  - —estimates of potential revenues and effects of possible shortfalls;
  - —availability and suitability of proposed technology; and,
  - —environmental, economic, and transportation impacts on the region, and on other transport modes.

- *Because* benefits and costs of a high-speed rail system are so dependent on the actual ridership achieved, it would be desirable to have better data from which to estimate future passenger demand. Experimental verification of the importance of individual factors that affect ridership would be particularly useful. Congress may wish to determine whether it is feasible for the Department of Transportation to support such experiments.
- The relationship between institutions, including Amtrak and possible private rail operators, as well as State and Federal agencies, should be further clarified.

Chapter 2

HIGH-SPEED RAIL TECHNOLOGIES AND FOREIGN EXPERIENCE

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Chapter 2
HIGH-SPEED RAIL TECHNOLOGIES AND FOREIGN EXPERIENCE

In this assessment, a high-speed passenger rail system is defined as one that can attain speeds of 125 mph or more. With the exception of the Northeast Corridor (NEC) in the United States where trains now achieve speeds of 120 mph on some parts of its right-of-way, all development and use of these systems has occurred abroad.

This chapter examines the high-speed rail operations of foreign countries and, on the basis of that analysis, describes the technology options for high-speed rail service, and the various conditions that may make one option more attractive than the others.

SUMMARY

The technological options for high-speed rail service include combinations of equipment, track, and power systems. Two of the equipment and track options—conventional equipment on upgraded track, and state-of-the-art equipment on new track or on partly new track—are now employed in the regular high-speed passenger rail service offered by Great Britain, Japan, and France. Advanced technology (tilt-body equipment) on existing track is being actively pursued by Britain and Canada, but is not yet fully developed or implemented. The final equipment, track, and power option—the ultra-high-speed mode, magnetic levitation (maglev)—is still in the developmental stage in West Germany and Japan. Of the propulsion system options, either diesel or electric are used on all state-of-the-art trains. A brief discussion of each of these technology options is presented below.

Equipment and Track Options

Improved Conventional Equipment Run On Upgraded Existing Track (Great Britain, United States, Canada)

This least-cost option uses conventional equipment at a maximum speed of 125 mph on existing track shared with freight and/or commuter trains. Foreign experience, particularly in Great Britain, shows that such equipment can run comfortably and safely at speeds of 125 mph. Grade crossings usually are eliminated on high-speed sections. Stringent safety precautions are required where freight shares the high-speed route with the passenger trains. Frequencies of service are contingent on coordination with freight and commuter services and are adversely affected when the speeds of each service differ widely.

New technology applied to vehicles and signal and control systems make faster trips possible on existing track. At speeds of more than 125 mph, however, automatic speed controls are desirable as are technologies that reduce weight and pressure on the track. Where speeds are limited by curves, the use of tilt-body vehicles (if further developed) might improve trip times. Above 125 mph, complete grade separation is essential, and, on the high-speed sections, tracks cannot be shared with other types of trains.

State-of-the-Art Equipment, Partly or Totally New Track (France, Japan)

Where speeds substantially above 125 mph are desired, dedicated track becomes essential. The equipment must be designed to new and more stringent specifications to keep the ride quality and the forces exerted on the track within the proper limits. Lightweight materials, new and sophisticated signaling, and train control systems are required, and radii of curves must be increased. For relatively small changes in elevation en route, heavier gradients can be used to reduce the need for expensive viaducts and cuts.

This option technically allows for design speeds up to 200 mph on new track between cities,

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though lower speeds typically are used in revenue service. The French avoided the major capital expenditure of new track into city centers at the cost of lower speeds (125 mph maximum) at each end of the trip. The Japanese, because of overcapacity on existing lines and unsuitable track gage, constructed totally new track for their bullet train.

Very High-Speed New Modes—Maglev (Developmental: West Germany, Japan)

Maglev is the only new surface mode for high-speed intercity transport still in the development stages. Speeds in excess of 250 mph are possible using such systems. The Japanese have tested an experimental vehicle at 320 mph. The West Germans are beginning final testing of their maglev vehicles this year. Theoretical operating costs for a maglev system have been projected to be lower than those of a conventional new high-speed railway corridor, however, verification of operating costs under conditions that fairly reflect revenue service await test results.

Maglev would be competitive with air travel from station to station on routes characterized by high population densities at one or both ends, "travel affinity" between the cities, and long distances between stops.

Propulsion System Options

Diesel Power

The diesel power unit carries its own primary power supply (the diesel engine) with fuel for 1,000 miles or more. It uses an onboard generator to provide electric power to motors that drive the axles of the power car and to provide heating, cooling, ventilation, and lighting. Although limited in size and weight, the diesel-powered train is very flexible and can be moved around the system as traffic needs dictate. Nevertheless, a design speed much higher than 125 mph is regarded as impractical by engineers because of power constraints inherent in diesel traction.

Electric Power

Electric locomotives basically are simpler, lighter in weight per horsepower, and cheaper to maintain than diesel locomotives. They make it possible to use at least twice as much power continuously as a diesel locomotive, with a significantly higher short-term power output and acceleration rate, as well as improved braking. However, the necessary overhead power supply installations and substations are very expensive, and existing signaling systems usually require renewal to prevent magnetic interference from the traction system. Replacement of signaling systems also is required to accommodate safe train spacing at higher speeds. To transfer the amount of power needed, high voltage systems are a necessity, usually by means of an overhead power supply. Whatever traction is used, as speed increases, unsprung axle load* must be kept to lower values to avoid too great an impact on the track and vehicle. Unsprung axle load can be reduced by suspending heavy electric motors on the truck above the primary springs or on the vehicle body itself with flexible drive. Total weight on each axle also is important and must be reduced as speed increases to ensure good ride quality.

Gas Turbine Power

While gas turbine power units offer the advantages of rapid power buildup and are very lightweight, the escalating fuel costs in the 1970's and the engine's lower efficiency except at full power led to the virtual abandonment of this technology.** Turbotrains, which use gas turbine engines, are run routinely from Buffalo to New York.

Linear Motors

To date, electric propulsion has used rotary motors carried on the train. With linear motors, the magnetic parts of the conventional rotating motor are replaced by a passive element on the vehicle and an active element in the track that interact to accelerate, maintain speed, or decelerate the train. Problems of power transmission and wheel to rail adhesion may be reduced by linear induction motors (LIMs). The first commercial installations of LIMs (noncontact propulsion) for

* Unsprung axle load is the weight not supported by springs, and therefore in immediate contact with track structure. This type of contact will result in higher impact loads for the same weight because of the absence of a cushioning effect of the springs.

** However, the French National Railways (SNCF) still operates a few trains at 100 mph maximum speed.

revenue operation are under construction now as *low-speed* transit lines in Toronto, Vancouver, and Detroit.

Maglev vehicles use linear motors for noncontacting propulsion. A variety of such motor types have been developed and tested with maglev vehicles; however, only the *linear synchronous motor (LSM) currently is being developed for high-speed applications.* While the principle of linear motors is simple, maglev requires a sophisticated power conditioning and distribution system to control the proper amount and frequency of electrical power for propulsion.

Comparison of various propulsion system options, indicates that diesel power is flexible and does not require a large capital expenditure for fixed installations for power supply. However, it limits train size and speed. Electric propulsion depends on expensive fixed installations but offers much higher power to weight ratio and thus larger and faster trains. For frequent service, it is simpler and cheaper to operate than the diesel and does not necessarily depend directly on oil as fuel. Gas turbine power has been discarded because of high fuel consumption and maintenance cost. LSMS for maglev systems theoretically offer very high speed at reduced costs but require new guideway construction, and sophisticated power conditioning systems.

Foreign Experience

France, Great Britain, and Japan now operate rail services at 125 mph and above. However, each country tailored its system to its own unique demographic and transport needs and to its geography. Consequently, significant differences exist among these three high-speed passenger rail systems.

France uses existing track into and out of Paris and Lyon and new track between the population centers and state-of-the-art vehicles that were developed jointly by French National Railways (SNCF) and French manufacturers. The equipment is being used on other routes as well. The French system, TGV (Train a Grand Vitesse), has exceeded 200 mph in test runs. In actual service, its top speed initially was restricted to 160 mph, though it was recently increased to approximately 170 mph.

Great Britain uses conventional equipment (diesel- and electric-powered lightweight trains) on *existing track* at maximum speeds of 125 mph. The British decided not to build new track because of projected high costs and probable opposition on environmental grounds. Great Britain and Canada also are developing separate versions of tilt-body equipment, designed to improve train speeds on curves through the use of tilt mechanisms. Viable commercial application of tilt-body equipment is still in question.

Japan's Shinkansen bullet train system uses *state-of-the-art equipment on completely new track.* The trains are designed for speeds of 160 mph, although they currently are operated at 131 mph. The original Tokyo-Osaka bullet train was built to alleviate the overload on the existing rail route and to meet new traffic demand. During the first 5 years of operation, ridership increased substantially. Later, additional extensions and routes were built. Because population densities are lower in the areas served by the newest routes, the ridership is less, and train numbers and sizes are smaller. Economic success is likely to be more difficult to achieve with the recent lines.

The French, British, and Japanese vehicles all could be adapted for suitable existing track in the United States, although the TGV and Shinkansen vehicles cannot operate at full design speed without new track and signaling equipment. The Japanese built entirely new track, in part, because they could not interrupt service on their existing lines. With the new right-of-way, they also reduced the number and degree of curves and built a wider (standard) gage, rather than the narrow gage used by the rest of the system. The French and British trains are designed for electric and diesel traction respectively, but could be redesigned for the alternative. Every car in the Japanese trains is electric-powered.

Electric power requires expensive wayside facilities to enable the trains to pick up current for traction and train use. Thus, the lowest capital requirement is for diesel-powered trains. High ridership is required before the benefits or revenues of electric traction can overcome the additional fixed capital cost. However, the use of existing track avoids the very high capital expenditure required by new track, with either diesel or electric traction. The costs of building new track, although always higher than upgrading existing track, can vary greatly with topography. The construction cost of the French line, for example, is reported at $4 million per mile, in part owing to the relatively open country. The two latest sections of the Shinkansen are estimated to have cost about $35 million to $40 million per mile, due to the high percentage of tunnels and viaducts that had to be constructed. Earlier Shinkansen lines cost approximately $20 million per mile in 1979 dollars.

DISCUSSION

In recent years, several foreign railways have operated conventional equipment at speeds in excess of 100 mph, the previously accepted maximum speed of operation. The Japanese National Railways (JNR) opened its Shinkansen (131 mph maximum) in 1964, which from the outset was a phenomenal success. The first sector was followed by a second completed in 1975, and two more sectors recently have been added.[1] In 1975, British Railways (BR) inaugurated the first daytime high-speed passenger train line on tracks shared with other trains. It has since opened five other such lines. In France, a new high-speed line from suburban Paris to suburban Lyon used by TGV has been built. It permits operation at speeds up to 170 mph (with potential of 186 mph) and will be fully operational in 1983. It has been in limited use since 1981.

Current plans for additional high-speed trains include, in Britain, the introduction of a tilt-body train at 125 mph connecting London, Glasgow, Manchester, and Liverpool. France plans a line serving Bordeaux and Rennes, and in West Germany, two new sections of railway are under construction to be used at maximum speeds of 125 mph.

[1]Japanese National Railways, "Shinkansen," February 1982.

Conventional Equipment on Existing Track

France

With the introduction of diesel and electric traction in the 1960's, maximum speeds of 100 mph became commonplace. Regular use of maximum speeds of 125 mph first occurred in France when SNCF introduced a limited number of trains on three routes. Normally, such speeds were limited to morning and evening trains to and from Paris with first class accommodation at a supplementary fare.[2] Table 2 shows trip times and speeds for major flows.

Most trains on each route operated no faster than 100 mph. The high-speed trains were aimed at the business market, against growing air competition. A small number of special locomotives were built and used with new conventional coaches (known as "grand comfort"). No special attention was given to the track, and existing signaling was used.

West Germany

The Deutches Bundesbahn (DB) introduced a small number of locomotive-hauled trains at 125

[2]SNCF.

Table 2.—SNCF 125-mph Trains

		Overall trip time		
Sector	Miles	Hours	Minutes	Average speed (mph)
Paris — Bordeaux	363	3	50	95
Paris — Limoges	250	2	50	88
Paris — Dijon	197	2	19	85
Paris — Lyon	320	3	47	85

SOURCE: SNCF Timetable.

mph, and an experimental electric multiple-unit train ran for a period between Munich and Hamburg.[3] These trains, like the French, were placed on the existing network as a separate luxury service at supplemental fares.

Details are not available on costs of these high-speed services, but both SNCF and DB state that the extra maintenance costs for the trains were offset by the increased mileage per vehicle, so that extra cost resulted only from the additional fuel consumed at higher speeds.

Great Britain

BR is operating complete routes at maximum speeds of 125 mph on existing track. The British considered the possibility of a new high-speed railway similar to the Japanese system, but rejected it because of extremely high projected capital costs and anticipated environmental opposition. Instead they designed high-speed trains (known in Britain as "HSTs") for existing track, at wear-and-tear levels equal to the existing intercity trains, but with maximum speeds of 125 mph and braking systems capable of stopping the trains within the distances provided by the existing signaling. All main routes were examined for opportunities to reduce trip times by eliminating speed restrictions and upgrading line at moderate capital expenditure. When applied to U.S. conditions, BR officials estimate that upgrading for high-speed trains approximates $2.5 million per mile, * though it can vary considerably by route and condition of the track.

[3]DB Timetable.

* British Rail data extrapolated to U.S. track conditions for a Michigan corridor.

Photo credits: TRANSMARK

British Railways High Speed Train: insert shows the interior

In addition to the HST designs, and to prevent having to develop totally new railbeds to meet long-term needs, the British decided to develop the advanced passenger train (APT), which has a tilt mechanism** to improve speeds on curves. To date, however, APT has been delayed by technical difficulties.

First introduced in the mid-1970's, HSTs now provide daytime service on six routes, a total of 18 million train-miles per year, at speeds up to 125 mph.[4] They are standard intercity trains, available to all riders, and marketed with the full range of selective fares offered on the whole intercity network.

The characteristics of the lines where HSTs were introduced varied widely. On some routes, up to 50 miles between stops was common; others had nonstop runs of up to 220 miles. Table 3 gives a cross section of trip times and speeds before and after introduction.

In 1982, HSTs ran 18 million train-miles and probably will continue at this level. BR officials state that ridership increases of 30 percent have been achieved in areas where there already was a major intercity route.[5] HST service reportedly covers operating costs (including depreciation) and makes a significant contribution to track and signaling costs. However, it does not earn enough revenues to repay full expenses and capital investment, typically running 10 to 15 percent short.

The 87 HSTs sets now in service provide 205,000 miles per year each. This compares with 100,000 to 150,000 miles per year by the diesel locomotives the HSTs replaced.'

•● The tilt mechanism reduces lateral forces on passengers and is analogous to banking in an aircraft.

'British Rail Information.

'Contractor discussions with British Rail Passenger Department.

[6]British Rail statistics.

New Equipment on Existing Track

Great Britain, Canada

BR has continued development of APT. This train has advanced concepts including a hydrokinetics braking system, * articulation (using one truck to support the ends of adjoining cars), and an active tilting system. APT has experienced persistent troubles and is still undergoing refinement to the tilting mechanism. APT is designed for speeds of **150** mph, but could be engineered to 200 mph. Present plans are to use APT for all daytime service on the electrified lines at 125 mph within 5 years.[7] APT operating costs per passenger-mile are expected to be comparable with HST, with the additional costs of maintaining the tilt mechanism being offset by improved fuel economy.[8]

The Canadian LRC train (light, rapid, comfortable) also features an active tilt-body system designed to improve trip times by better performance on heavily curved track.

In 1981, two LRC train sets were leased to Amtrak for 2 years with an option to purchase. At the end of the lease, they were returned to the manufacturer (Bombardier), Amtrak having decided that the benefits in reduced trip times did not offset the disbenefits of lack of compatibility with other equipment. In addition to British and Canadian tilt-body equipment, Swiss, Italian, and Swedish manufacturers are also developing such equipment.

● Hydrokinetics braking is a nonwearing braking system which allows the train's kinetic energy to be converted into heat in the braking fluid rather than heat in a braking disk or wheel tread.

'British Rail officials.

[8]D. Boocock and M. Newman, *The Advanced Passenger Train,* **(London: Institute of Mechanical Engineers, December 1976).**

Table 3.—HST Comparison of Trip Times

Sector	Miles	Before HST: Time (hours/minutes)	Before HST: Average speed (mph)	With HST: Time (hours/minutes	With HST: Average speed (mph)
London — Reading .,	32	0.30	72	0.22	98
London — Chippenham	94	1.27	58	0.54	104
Reading — Swindon	41	0.44	56	0.26	95
London — Bristol	112	1.55	62	1.05	103
London — Doncaster	156	2.12	71	1.39	95
London — Newcastle	269	3,35	75	2.57	91

SOURCE: British Rail Timetable,

Generally, tilt-body equipment has some problems that remain unresolved, particularly commercial viability of the equipment due to maintenance costs.

State-of-the-Art Equipment on New Track

The construction cost of new track is high and typically *is* considered for use with state-of-the-art equipment only where existing track is unsuitable. Some situations may require the construction of new track for high-speed trains, e.g., where the tracks have been used extensively by other trains, or where the tracks may be completely unsuitable for high speed.

Japan

In Japan, the existing lines were both unsuitable for high speed and overloaded with traffic. Ridership was expected to increase rapidly. There was no question of running high-speed trains on the existing track because of narrow track gage, nor of running more trains to increase capacity. The new railway built by JNR had a design speed of 160 mph, although until now it has been operated at a maximum of 131 mph.

The World Bank provided part of the original financing for the first bullet train. The 320-mile line between Tokyo and Osaka (Tokaido) opened in 1964 and was an immediate success. Circumstances were especially favorable for development of a high-speed railway:

1. the existing railroad line, the predominant transportation system, was overloaded;
2. traffic was expanding rapidly;
3. competition from road and highway use was minimal;
4. the costs of a new highway (as an alternative) were estimated at more than five times that of the railway; and
5. there was a fully developed transit feeder system. Japan at that time did not build an interstate system for automobile use.

Table 4 shows ridership figures for the original Shinkansen as well as ridership resulting from the additions built from 1972 to 1975. While ridership increased dramatically on the Shinkansen, it began dropping on the conventional routes, as shown in figure 1. Ridership on the conventional route stabilized in the early 1970's while Shinkansen ridership grew with the addition of the Okayama extension in 1972 and the Hakata extension in 1975. The average distance traveled per passenger remained fairly constant. Ridership for the entire line peaked at 157 million (33,3oo million passenger-miles) in 1975. However, fare increases (resulting from overall JNR system deficits) reduced demand by about 20 percent in the late 1970's, and ridership stabilized at about 125 million annually in 1980. With the extension from Tokyo to Hakata, the route mileage increased to 663. The express trains call at a limited number of major cities, with the second service reaching stations not served by the faster trains.

Photo credit: ISP Photo by Joan Bluestone

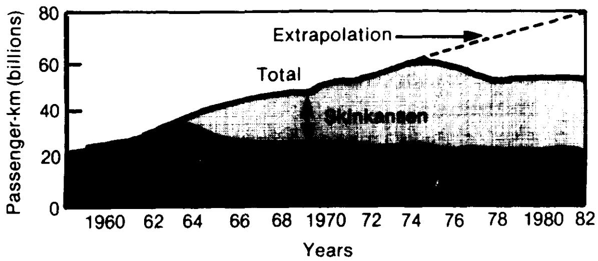
Shinkansen Bullet Train in station

Table 4.—Ridership: Shinkansen, 1965-70, 1975.80

Year	Passengers (millions)	Passenger-miles	Average distance per passenger (miles)
1965	31	6,658	213
1966	44	9,058	205
1967	55	1 1,18a	200
1968	66	13,139	198
1969	72	14,270	198
1970	85	17,454	204
Line extensions occurred-1972, 1975:			
1975	157	33,300	210
1976	143	29,850	208
1977	127	26,160	206
1978	124	26,700	206
1979	124	25,400	205
1980	126	25,900	205

SOURCE: Japanese National Railways, "Shinkansen," February 1982; Japanese National Railways, *Facts and Figures, 1981* edition.

Figure 1.—Rail Travel: Tokyo - Osaka



Year	Pass. km (billions)	Increase	Average annual increase
1964	38.5	—	—
1980	53.1	38%	2%

SOURCE: Ichiroh Mitsui, Japanese National Railways.

As of October 1982, according to JNR, *express* trains between Tokyo and Hakata carry approximately 69 percent of all passengers on the route. On weekdays, 58 percent of travel is for business reasons. Access to the rail station is approximately 75 percent by public transit, 20 percent by taxi, and 5 percent by auto. Access from the train to final destination is 60 percent public transit, 35 percent taxi, and 5 percent auto.[9]

Between Nagoya and Osaka on the original (Tokaido) section, 204 trains are run daily. On the three sections between Osaka and Hakata, this number reduces to 131 trains, 100 trains, and 75 trains.[10]

Two new northern lines, the Tohoku and Joetsu, have been opened recently. The new lines start from Omiya, a suburb of Tokyo, with access by a shuttle service on existing tracks. It will be some time before the connection from Omiya to Tokyo is completed (see fig. 2). The scheduled trips are fewer on the two new lines than on other Shinkansen sectors, and the trains have only 12 cars instead of the standard 16 used on the Tokaido Shinkansen. Ridership on the new lines is expected to be less than on the existing network, and revenue is likely to fall short of operating costs. JNR expects that these two sectors eventually will become profitable, but there are substantial doubts about the remainder of the planned network* because the ridership forecast in sparsely populated areas is less than 10 percent of the capacity of the proposed new lines.[11]

Tables shows the trip times and average speeds for the two new sections of the Shinkansen service.

The construction of the new lines has been expensive, largely as a result of the very difficult climatic conditions, difficult terrain, the need for shallow curves and easy gradients to permit speeds of 160 mph, and the high cost of providing access to cities. Table 6 shows the proportion of each Shinkansen line in tunnels or viaducts. Because of the Japanese terrain, Japanese engineers working on the Shinkansen system have become the world leaders in tunneling technology.

The two latest sections are estimated to have cost about $35 million to $4o million per mile, while the earlier routes were estimated to cost about $2o million per mile in 1979 dollars.[12]

The original section from Tokyo to Osaka has been highly profitable, and the sections from Osaka to Hakata currently are recovering costs. Operating costs for 1980 were reported by JNR as 4.3 cents per passenger-mile, with total costs as 6.9 cents per passenger-mile. Revenue earned was 11.7 cents per passenger-mile. From a review of JNR's trends in operating ratios, it is apparent that opening lines south of Osaka did not significantly improve the overall financial performance of the system. The operating ratio (costs to revenues) was a low of 0.44 in 1970. A decade later in 1980 it was 0.59; still a better ratio than anywhere else in the world.[13]

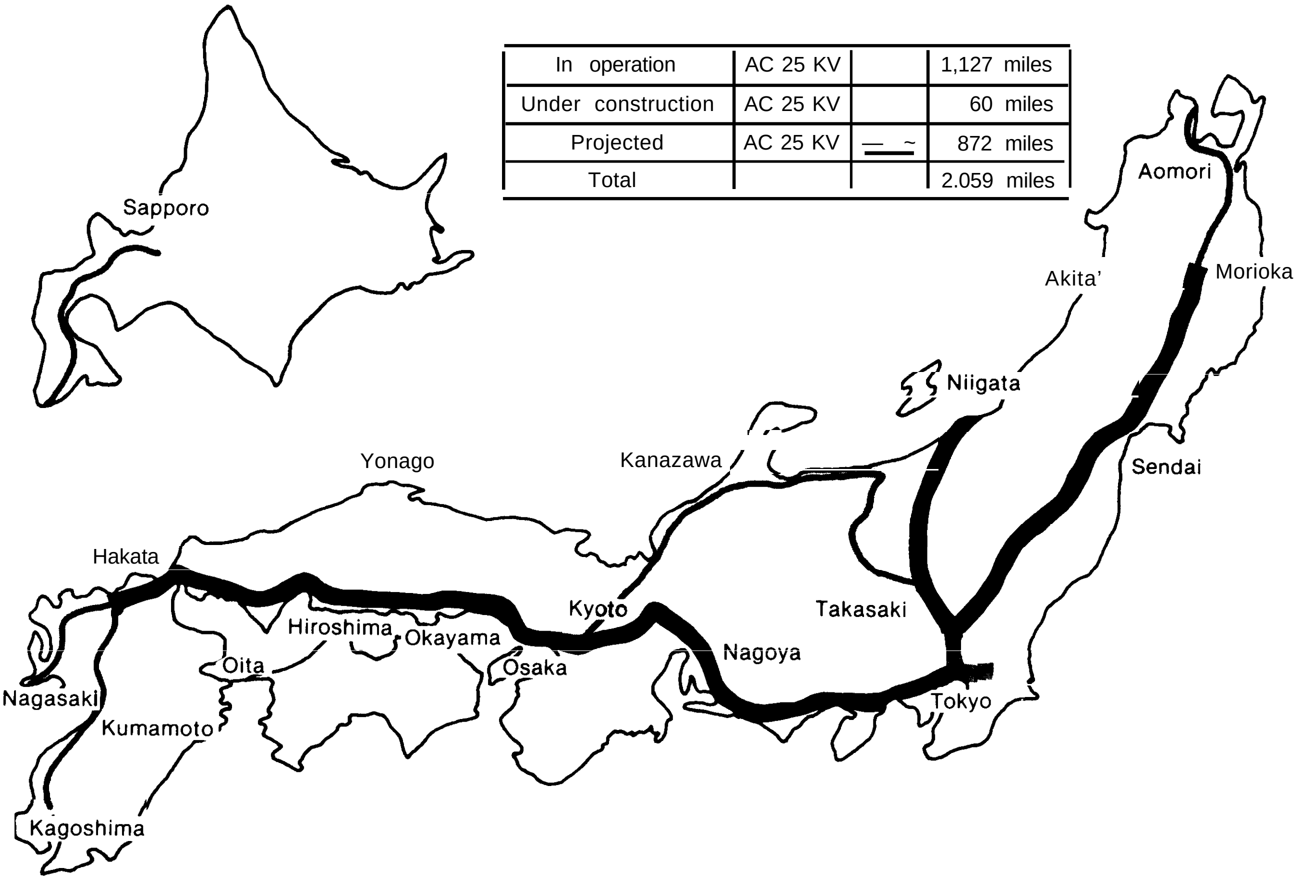
The first section that opened between Tokyo and Osaka created a great deal of opposition because of noise and vibration. Later sections featured construction methods designed to reduce noise and vibration, including noise barriers on certain sections. Because of the original problems, however, there has been very vocal opposition to increasing the speed to 160 mph. However, JNR still expects to increase speeds to perhaps 140 mph soon as a first step toward achieving design speed (160 mph) for the line and equipment. While the

[9] Ichiroh Mitsui, Japanese National Railways representative, Washington, D.C.
[10] Japanese National Railways, op. cit.
* JNR anticipates building additional Shinkansen lines however, whether this construction will occur appears uncertain according to recent trade journals.

[11] Mitsui, op. cit.
[12] Ibid.
[13] Japanese National Railways, oP. Cit.

Figure 2.—Japanese National Railways Standard Gage (Shinkansen) Lines

As of January 1983



SOURCE: Japanese National Railways.

Table 5.—Trip Times on Shinkansen

	Miles	Before trip-time (hours/minutes)	Average speed (mph)	Shinkansen trip-time (hours/minutes)	Average speed (mph)
Omiya-Marioka	291	5.37	52	3.17	89
Omiya-Nigata	168	3.30	48	1.50	92

SOURCE: Japanese National Railways.

Table 6.—Proportion of Tunnels and Viaducts

	Tunnel		Viaduct		Other		Total viaduct and tunnel	
	Miles	Percentage	Miles	Percentage	Miles	Percentage	Miles	Percentage
Tokyo — Osaka	43	13	36	11	243	76	79	24
Osaka — Hakata	176	51	32	9	138	40	208	60
Omiya — Marioka	72	23	49	16	189	61	121	39
Omiya — Niigata	66	39	19	11	84	50	85	50

SOURCE: Ichiroh Mitsui, Japanese National Railways Representative, Washington, D.C.

early bullet trains have been highly successful in terms of ridership and costs, the entire JNR system, like those of other countries, experiences financial problems.

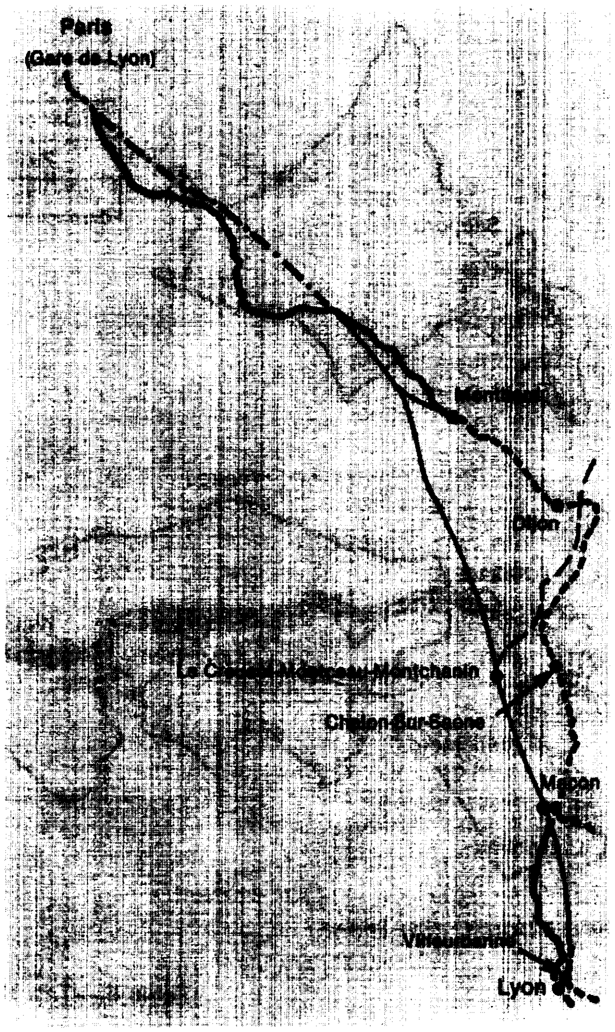
France

In France, the use of conventional trains at 125 mph demonstrated the benefits in ridership from faster trip times. In the late 1960's, the French Government faced two choices for relieving severe congestion in the Dijon area: add tracks in the hilly area approaching Dijon, or build a completely new line diverting a major part of the intercity passenger train service away from the congested areas. The Government decided to build a new line (see fig. 3).[14] The French have maintained national policy of promoting their rail service. As a part of that policy, intercity bus travel on highways and expressways has been prohibited in order to encourage rail use, according to SNCF officials. Buses are permitted on other roads.[15]

The French designed their system to fit their needs and topography. It used existing track into Paris and Lyon, eliminating the high construction costs in urban areas. The intermediate sections of line pass through sparsely populated areas. Gradients, mainly into and out of river valleys, were negotiated at up to 3.5 percent, eliminating the need for expensive tunnels and requiring only 2 miles of viaduct. The line has excellent feeder systems serving surrounding Dijon and Lyon, and existing routes provide good access to many cities farther south. The long distances with few intermediate stops afford maximum opportunity to utilize the trains' speed—currently to 170 mph, with an average speed between Paris and Lyon of 133 mph. The Paris to Lyon TGV line includes **244** miles of new track. The remaining mileage used existing right-of-way into Paris and Lyon.

SNCF estimates the construction cost was $4 million per mile. Total land acquisition was about 9 square miles. Ridership forecasts were for 25 percent of the total between Paris and Lyon and the remaining from the wider areas surrounding the end points. In just over 1 year, the French have achieved 5.6 million riders on the Paris-Lyon axis alone and in 16 months the ridership has increased to 10 million. SNCF officials are confident of reaching the forecast of 16 million riders for the whole network by 1987. Revenues in the first full year were reported $140 million, and operating costs were estimated at $70 million, with revenue per passenger-mile estimated at 10 cents and costs

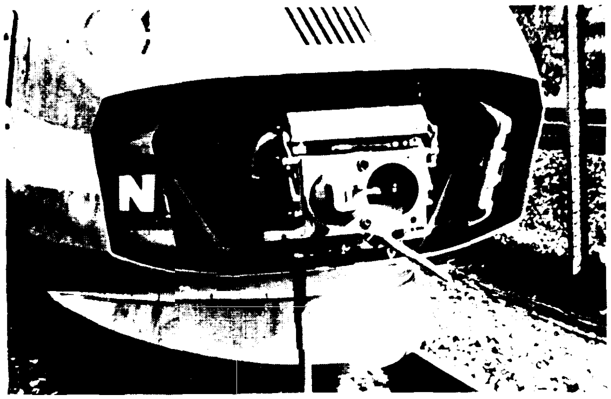
Figure 3.—SNCF-TGV Line Between Paris-Lyon



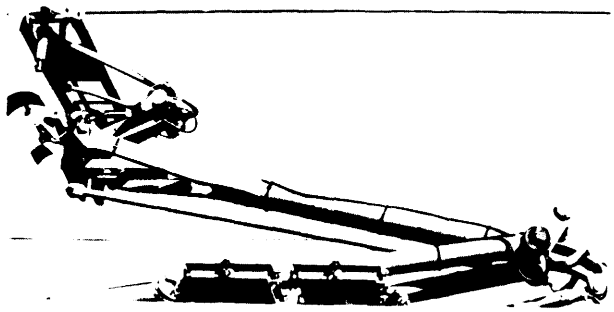
— New line in service as of October 1981
—•— New line in service as of October 1983
— Present Paris-Lyons line
' ' Present lines used by TGV trains in October 1981
— Present lines used subsequently by TGV trains

SOURCE: SNCF.

[14] Contractor discussion with SNCF officials.
[15] Hughes deVillele, French National Railways, U.S. Office.



TGV coupler



Pantographs for railcars used on the TGV

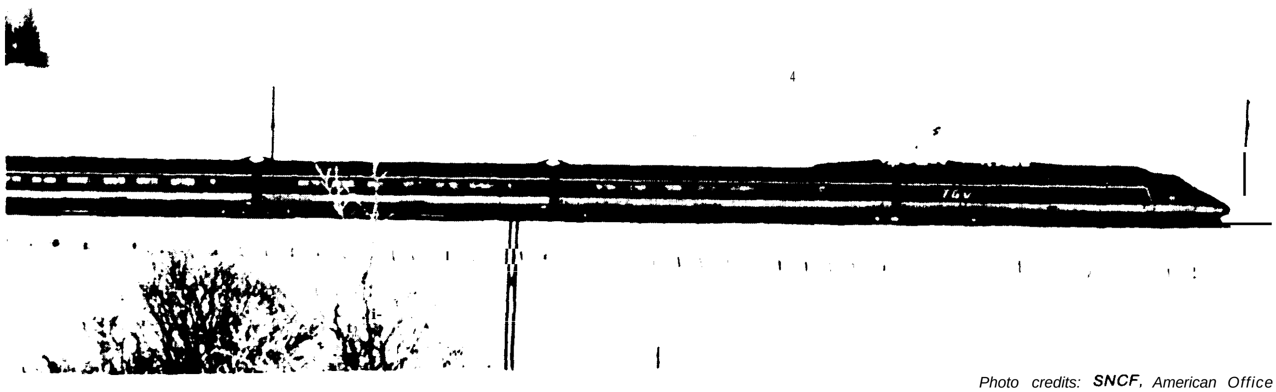


Photo credits: SNCF, American Office

TGV from Paris to Lyon

at 5 cents per passenger-mile. * SNCF expects to cover fully allocated costs (including track, signaling, etc.) in 1984 and to break even in 1989.[16]

When the new line is in full operation, **87** train sets will be used, of which **64** were in service at the end of 1982. Each set is expected to run between 280,000 and 300,000 miles per year. All maintenance is confined to one facility outside Paris, and most servicing is performed at a single facility, also at the Paris end of the route. New maintenance facilities were not constructed for the new TGV route. Sophisticated pantographs (for electric current collection) allowed for the use of a simple catenary (overhead wire system of power supply). The trains have been designed with overall axle weight of **161/2** metric tons (tonnes), and the vehicles are articulated (with one truck supporting the ends of two cars). Lightweight construction (64 tonnes per power car and 36 tonnes per passenger car) has reduced wear on the track

*Operating costs include different items for each railway and are not comparable with one another.

[16]SNCF.

and the new line is maintained to the standards required for 100-mph operation. Fuel consumption is less per seat-mile than the conventional trains displaced by TGV.[17]

Table 7 gives details of trip times and speeds for a selection of routes served by TGV. In each case, the times are those for full operation, planned for September 1983.

[17]Data provided b, SNCF-TGV Maintenance Facility officials, Villeneuve, Paris, January 1983.

SNCF plans the construction of a second line of 120 miles between Paris and Bordeaux, although the increased traffic forecast will be insufficient to pay interest charges on the investment. It will therefore only consider actual construction of this line if the government offsets the interest charges.[18]

[18]SNCF discussions.

Table 7.—TGV: Comparison of Trip Times

Sector	Miles (original route)	Conventional Time (hours/minutes)	Conventional Speed (mph)	TGV Time (hours/minutes)	TGV Average speed (mph)
Paris — Dijon	197	2.19	85	1.37	122
Paris — Lyon.	320	3.47	85	2.00	133
Paris — Marseilles	439	6.35	82	4.43	99
Paris — Besancon	254	3.30	73	2.21	108

SOURCE: TGV Timetable.

Chapter 3

FACTORS AFFECTING THE ECONOMIC FEASIBILITY OF HIGH-SPEED PASSENGER RAIL SYSTEMS

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Chapter 3

FACTORS AFFECTING THE ECONOMIC FEASIBILITY OF HIGHSPEED PASSENGER RAIL SYSTEMS

This chapter discusses the basic factors likely to affect the economic feasibility of high-speed passenger rail systems in the United States. It describes the overall size and character of the travel market required for a successful high-speed system as well as the basic service features that will enable a system to attract ridership. It examines methods for developing economic forecasts for a system and outlines the basic cost to revenue relationships of building and operating a high-speed service.

SUMMARY

OTA's analysis of the factors that influence transportation preferences and of the experience of foreign high-speed systems suggests that the following minimum corridor characteristics are important for economic feasibility of high-speed systems:

- cities with high populations and high population densities;
- cities with a strong "travel affinity" between them, generally because one is a dominant center of commercial, cultural, financial, governmental, or other activity;
- cities grouped along a route giving major passenger traffic flows in the 100- to 300-mile trip range; and
- cities with developed local transit systems to feed the high-speed rail.

Data on current U.S. travel, aggregated on a national basis, show that automobiles and airplanes are the most extensively used modes for intercity travel. Rail represents less than 1 percent of current intercity revenue travel. *Nationally, rail's share of the intercity market is not likely to increase dramatically if additionalhigh-speed rail systems are built, because only a few U.S. corridors may be likely candidates for such systems.*

Considering speed and schedule frequency together, it appears that the major rail markets start at about 100 miles and reach up to 300 miles. Outside these limits, rail competes successfully only where special factors compensate for the relative disadvantage in trip time compared with the automobile at short distances, and aircraft at long distances. For shorter distances, the use of a high-speed rail is essentially equivalent to creating a transit system.

The overall ridership and the choice of travel modes by riders are determined by a number of interrelated factors: total trip times, speed, frequency, distance, cost, comfort, and convenience. Each of these factors, and the tradeoffs among them, must be examined for specific rail corridors. *In terms of time, what matters to the traveler is not the speed of the main mode used on any single trip but the total time (the trip time) it takes to travel—by whatever combination of modes—from departure to final destination.* Thus, the speed of the airplane may be offset by the time spent getting to and from airports or of getting around within airports. Conversely, the slower speed of the automobile is often outweighed by the fact that it does not involve the access, egress, and terminal waiting times—or the relatively infrequent departure times—required by the public modes.

Major purposes for intercity travel are business, family, and other private travel. For each of these trip purposes, the factors discussed above have different relative values. The business traveler places a high value on time and will pay for comfort and convenience. Thus, fare is often less important than trip time, frequency, comfort, or convenience. At the other end of the spectrum are riders for whom the cost of the trip is paramount. For example, a family of four would calculate the cost of a 200-mile round trip by automobile at perhaps $26 ($20 gasoline plus $6 parking), or

$6.50 per person. The family would find unacceptable the standard rail fare of about $100 plus access costs (over *$25* per person). Even a total round-trip fare of *$7o* for a family of four would be only nominally more attractive.

Frequency of service equates to increased convenience and attractiveness and can have the same perceived value to the customer as increasing speed.

High-speedrail systems are costly to construct. How costly depends on such factors as location, length of route, right-of-way, terrain, technology selected, and the service levels to be provided. The French estimate, for example, that the construction of their TGV cost an average of $4 million per mile. The Japanese estimate that the last two links of the Bullet Train will cost an average of between $35 million to $40 million per mile due to significant tunneling and viaduct requirements. The earlier links cost about $20 million per mile in 1979 dollars. For purposes of comparison, the *$35* million to $40 million per mile costs are similar to those of the Century Freeway in Los Angeles.

The costs of the infrastructure (land, track, signaling and control systems, terminals) will vary widely among corridors. Infrastructure costs depend on topography and technology selected. Operating costs primarily include maintenance costs for track and equipment and "over the road" costs such as the labor and fuel. As such, the operating costs can vary according to the technology selected and the corridor characteristics.

Travel demand required to support high-speed rail service can be much lower where existing track can be used or, alternatively, new track added to existing rights-of-way. *Demand must be extremely high to support newly constructed high-speed rail lines, even if the land acquisition costs for expensive city sections of the route are avoided by using the existing right-of-way. Demand also must be extremely high if it is to pay back all capital costs and to break even* on *operating costs.*

Mathematical models can be and have been used to develop forecasts of passenger demand, Such models, however, have suffered from the paucity of good data on automobile travel. The most prudent approach to developing reliable ridership forecasts is to construct a realistic multimodal profile of the traveler through in-depth surveys (similar to the National Travel Survey), then use that data to validate the computer model.

DISCUSSION

Market Size

All high-speed passenger rail systems are costly and require high ridership if they are to generate enough revenue to cover operating costs, let alone capital costs. Existing high-speed rail corridors including corridors between Tokyo and Osaka, the West Coast Main Line between London and Glasgow, and the Northeast Corridor (NEC) between Boston, New York, and Washington, D. C., typically serve only major population centers. Each corridor links very large cities that are between 100 and 400 miles apart, one of which dominates as a national center (although not necessarily the administrative capital city). Table 8 shows the population densities for the countries now operating some part of their intercity network of rail services at high frequency and speed and for the city pairs linked by high-speed rail service. It also shows population densities of selected U.S. cities.

Population and population density determine both the size and potential of the market to support the high-speed rail service and transit feeder systems. The greater the population density, the more highly developed the transit system is likely to be. The ability of the NEC to provide high-speed intercity rail service is aided by the substantial local transit systems feeding the high-speed trains. Unless there is a heavy concentration of population in a relatively small area, such an infrastructure is not feasible. Without a highly developed local transit system, i.e., "feeder system, " a great deal of the potential travel by high-speed rail is not likely to be achieved. Some argue that improved local transit should be part of the plans

Table 8.—Population Density (approximate)

	Population 1980 (000s)	Area (mi²)	Population density per square mile	Approximate "radius" (mi)
U.S. population density:				
Chicago (S)(C)	3,005	228.1	13,174	9
SMSA	7,104	3,723.6	1,908	
Detroit	1,203	135.6	8,874	7
SMSA	4,353	3,939.0	1,105	
Cleveland	574	79.0	7,264	5
SMSA	1,899	1,519.7	1,250	
Cincinnati	385	78.1	4,935	5
SMSA	1,401	2,139.0	655	
St. Louis	453	61.4	7,379	4
SMSA	2,356	4,967.6	474	
Miami	347	34.3	10,113	3
SMSA	1,626	1,955.3	831	
New York(S)(C).	7,072	301.5	23,455	10
Newark (S)(C).	329	24.1	13,662	3
Philadelphia(S)(C)	1,688	136.0	12,413	7
SMSA	4,717	3,531.7	1,336	
Baltimore (S)(C)..	787	80.3	9,793	5
SMSA	2,174	2,246.9	968	
Washington, D.C. (S)(C)	638	62.7	10,181	5
SMSA	3,061	2,809.7	1,089	
Los Angeles	2,967	464.7	6,384	12
SMSA	7,478	4,070.1	1,837	
San Diego	876	320.0	2,736	10
SMSA	1,862	4,211.6	442	
Anaheim	219	41.7	5,259	4
SMSA	1,932	797.8	2,422	
All USA	229,300	3,615,000	60	
Foreign population and density—Japan Corridor:Tokyo-Hakata:				
Tokyo (S)(C)	11,649	357.3	32,604	11
Kyoto	1,470	70.7	20,796	5
Osaka (S)(C).	2,648	97.7	27,106	6
Okayama	546	42.8	13,107	2
Hiroshima	899	50.4	17,859	4
All Japan	117,059	147,517	794	
Foreign population and density—France:				
Paris	8,548	827.1	10,335	16
Dijon	208	52.3	3,988	4
Lyon	1,171	278.7	4,201	9
All France	53,500,000	213,000	251	
Forelgn popu/ation anddenslty—United Kingdom:				
Greater London.	6,900	621	11,105	14
Outer metropolitan area	5,400	3,557	1,518	—
Total	12,300	4,178	2,944	36
West Midlands Metrop County	2,700	353	7,652	11
Includes Birmingham	1,007	81.6	12,335	5
Greater Manchester	2,617	499	5,243	13
Merseyside	1,500	252	5,962	9
Includes Liverpool	504	44.1	11,418	4
Lothian	736	100	7,360	6
Includes Edinburgh	446	527	8,463	4
Central Clydeside	1,700	666	2,552	15
Includes Glasgow..	763	61.3	12,447	4
All United Kingdom	—	50,300	910	

KEY: S=Subway, C=Commuter.

SOURCE: U.S. Department of Commerce, 1980 Census of Population, PC 80 Series, February 1882; Far East and Australia Statistics, 1881-82) Europa Publications; Whittaker's Almanac, 1983; U.K. Statistical Yearbook, 1981, by HerMajesty'sSt atistics Office.

for high-speed rail systems. However, such systems are in themselves extremely costly and unlikely to be justified solely on the grounds of providing feeder service to high-speed systems.[1] According to Japanese National Railways (JNR), as of October 1982, access to the Shinkansen from home to station is 75 percent by public transit, 20 percent by taxi, and 5 percent by auto. Access from the train to final destination is 60 percent public transit, 35 percent taxi, and 5 percent auto.

[1]A study of "The Full Costs of An Urban Work Trip" concluded: "Given that practically all commutation corridors in the (San Francisco) Bay Area have peak traffic densities below 20,000, it would seem possible that BART trips were costlier to provide than the auto trips they were supposed to supplant. . . . Given these results, it would appear that the only circumstance under which it could make economic sense for a metropolitan area with characteristics of the San Francisco Bay Area to build a new fixed-rail transit system such as BART would be if a very large fraction of commuters were willing to pay a stiff premium price, in both fares and in their own time, for the privilege of riding a train instead of a bus." From Theodore E. Keeler, "Chapter III, The Full Costs of An Urban Work Trip: Auto vs. Bus and Rail Transit," *The Full Costs of Urban Transport* (Berkeley, Calif.: University of California, Berkeley, Institute of Urban and Regional Development, July 1975).

The Intercity Travel Market

Intercity travel consists of trips between urban areas conducted by airplane, bus, railroad, and automobile. Travel forecasts are as difficult to make as economic forecasts, and there is a wide divergence of views on the future growth rates in travel.

As presented in the aggregated data, air and automobile are preferred intercity modes of travel (see table 9). However, these patterns are likely to be less uniform between individual city pairs because modal choice depends on factors which

Table 9.—Intercity Passenger-Miles by Mode of Travel

	Automobiles[a]	Motor coaches[a]	Total motor vehicles[a]	Railways, revenue passengers	Airways, domestic revenue services	Total
Passenger-miles by mode (in billions):						
1981	1,344.0	27.2	1,371.2	11.8	216.0	1,599,0
1980[b]	1,300.4	27.7	1,328.1	11.5	219.4	1,559.0
1979[b]	1,322.4	27.2	1,349.6	11.6	228.2	1,589.4
1978[b]	1,362.3	25.4	1,387.7	10.5	203.2	1,601.4
1977[b]	1,316.0	25.7	1,341.7	10.4	177.0	1,529.1
1976[b]	1,259.6	25.1	1,284.7	10.5	164.4	1,459.6
1975[b]	1,170.7	25.4	1,196.1	10.1	148.3	1,354.5
1974[b]	1,121.9	27.7	1,149.6	10.5	146.6	1,306.7
1973[b] ., . . .	1,162.8	26.4	1,189.2	9.3	143.1	1,341.6
1972	1,129.0	25.6	1,154,6	8.7	133.0	1,296.3
1971	1,071.0	25.5	1,096.5	8.9	119.9	1,225.3
1970	1,026.0	25.3	1,051.3	10.9	118.6	1,180,8
1965	817.7	23.8	841.4	17.6	58.1	917.2
1960	706.1	19.3	725.4	21.6	34.0	781.0
Passenger-miles by mode (percent):						
1981	84.1	1.7	85.8	0.7	13.5	100%
1980[b]	83.4	1.8	85.2	0.7	14.1	100%
1979[b]	83.2	1.7	84.9	0.7	14,4	100%
1978[b] ., . . .	85.1	1.6	86.7	0.7	12.6	100%
1977[b]	86.1	1.7	87.8	0.7	11.5	100%
1976[b]	86.3	1.7	88.0	0.7	11.3	100%
1975[b]	86.5	1.9	88.4	0.7	10.9	100%
1974[b] ., . . .	85.8	2.1	87.9	0.8	11.3	100%
1973	86.7	2.0	88.7	0.7	10.6	100%
1972	87.1	1.9	89.0	0.7	10.3	100%
1971	87.4	2.1	89.5	0.7	9.8	100%
1970	86.9	2.1	89.0	0.9	10.1	100%
1965	89.2	2.6	91.8	1.9	6.4	100%
1960	90.4	2.5	92.9	2.8	4.4	100%

[a] Includes intracity portions of intercity trips, Omits rural t. rural trips, and intracity trips with both origin and destination confined to same city for local bus or transit movements, nonrevenue school and government bus operations.
[b] Revised.

SOURCE: Interstate Commerce Commission and Transportation Association of America.

vary by geographic location. Typically, distance between cities and trip purpose are two major factors influencing modal choice. For very long distances, the airplane is the preferred mode of travel; for shorter distances, the automobile. Between extremes, choices between carriers involve a compromise between two other critical factors—cost and speed. Business travelers, who place a higher monetary value on time than do nonbusiness travelers, tend to be more heavily influenced by speed than costs, though cost does factor in their decision. Nonbusiness travelers are also attracted by fast trip times, but are primarily concerned with total trip costs.

The automobile is the predominant mode of travel today in the United States. For any given intercity trip, people typically consider only the marginal costs of operating the automobile (fuel, tolls, oil, etc.)—rather than including the cost of the automobile—in comparing prices of one mode with another.

Market Requirements of a High-Speed Rail System

Any high-speed rail system must compete for riders with other public and private transport. Travel surveys show that ridership and choice of mode are influenced by several major factors: total trip time, speed, frequency, distance, cost, comfort, and convenience. Each of these factors, as well as the tradeoffs among them, must be examined in any market analysis of specific corridors.

Trip Time

The total time required to get from the point of departure to the final destination is defined as the trip time. This includes travel to and from the station or airport, access time or waiting time in the station or while parking, actual travel time, and egress time (time to obtain transportation from main mode to the final destination). Generally what matters to a traveler is the total elapsed time it takes from origin to destination rather than simply the speed of the mode used for the main part of the trip. Figure 4 portrays the modal choices for a hypothetical 100-mile trip available to a potential rider desiring to reach his arrival point at a set time. As the figure shows, all modes have a similar total elapsed time at a 100-mile distance despite the differences in speed between the main modes, assuming an hourly frequency for the public modes. Other assumptions concerning terminal access and egress, and the speed and frequency of the public modes, would swing the balance one way or the other. In general, the speed of the aircraft is tempered by the long access and egress times, while the slower speed of the automobile largely is offset by the fact that it does not involve the access and terminal service time of the public modes. Thus, the speed of the main mode cannot be considered apart from the extra access and service time required by that mode.

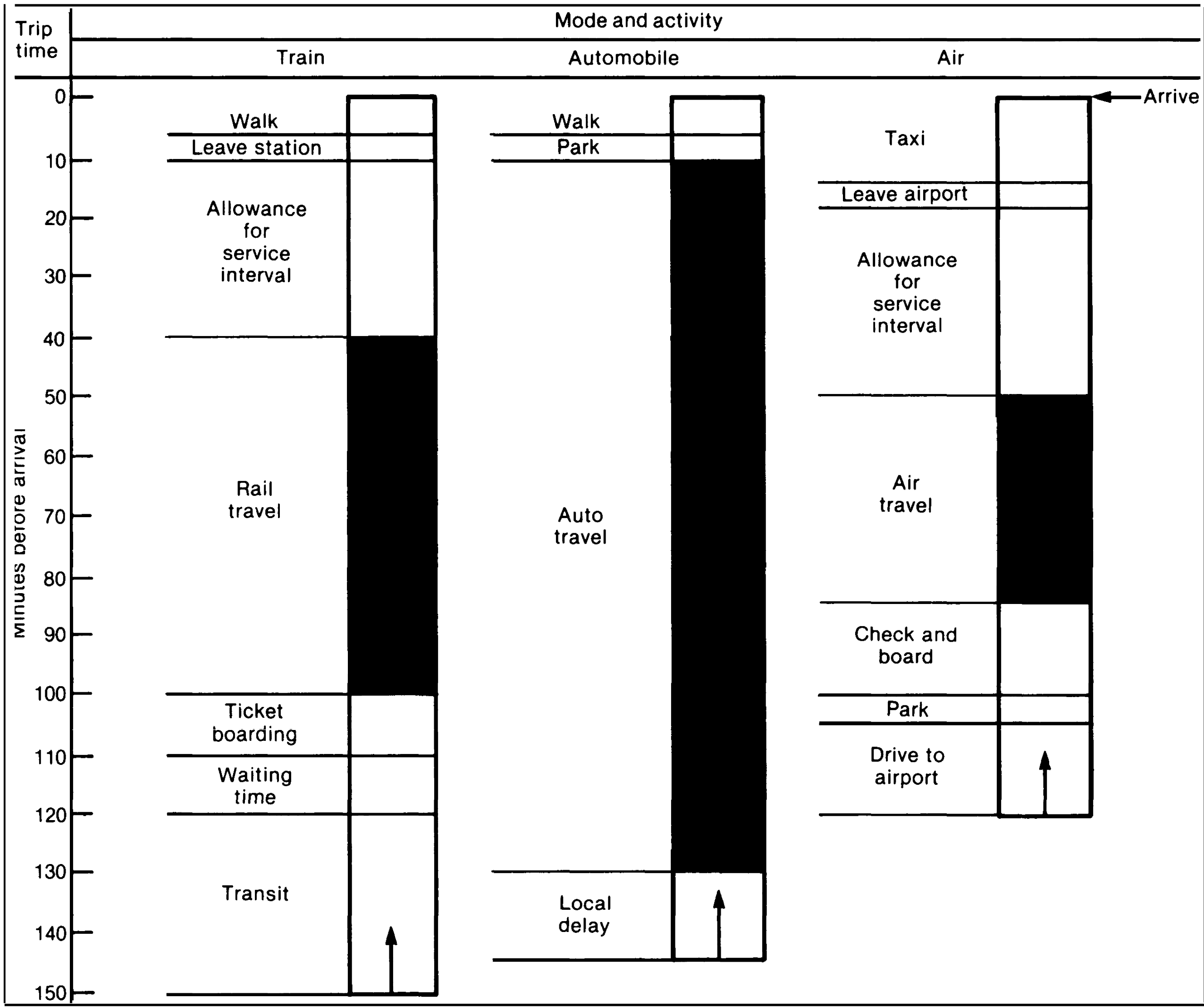
Frequency and Speed

There is a tradeoff between frequency and speed, where increased frequency can, to a certain extent, provide the additional attraction that increased speed can also give. The exact nature of this tradeoff is difficult to quantify. Figure 5 shows the effect of increased maximum speed *on* trip time for a 100-mile high-speed system.

The Effect of Distance

The relative value of speed will vary with distance, as shown in figure 6. At short distances, the transit bus and automobile dominate the market in both convenience and trip time. Rail is attractive for short trips only where special circumstances nullify the advantages of the automobile, such as peak time commuting access to a major city, center city congestion, cost of parking, access to airports or other major attractions for large numbers of people such as an exhibition center. In these cases, at short distances, frequency of service is essential, as is a single point of access. Travel time to and from stations is increasingly important to the individual traveler as trends show the U.S. population spreading out. Many people live further away from city centers, thus increasing travel times to and from stations and airports. Use of a rail link for airports usually involves some form of shuttle transport from the railhead to individual terminals, as at Logan Airport in Boston. Unless a high frequency service is maintained, all the benefit of a high-speed

Figure 4.—Components of Total Trip Time for a 100-Mile Trip (hypothetical)



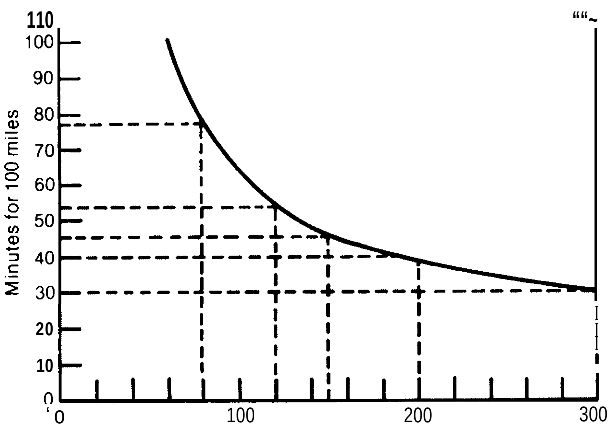
SOURCE: Jack Smith, Office of Technology Assessment contractor report.

movement will be lost in waiting time where trip distances are short.

As demonstrated in figure 6, for a trip of 30 miles the automobile has a substantial time advantage over a train that runs hourly at a 125-mph maximum speed. Increasing the top speed to 200 mph or even 300 mph still leaves rail at a substantial disadvantage in trip time. At this distance, increases in frequency do more than increases in speed to improve the trip times of trains. (Note that the figure assumes a nonstop rail trip. Each intermediate stop adds at least 4 minutes to trip time, and increases the rail trip time disadvantage.) For a trip of 50 to 100 miles, rail becomes progressively more competitive on trip time. At the lower end of the range, flows between intermediate stations will be confined to those trips where no automobile is available, or there are special circumstances favorable to rail.

At a distance of about 100 miles, the automobile loses all trip time advantage and competes only on price and convenience. At this distance, the trip time advantages of improved rail frequency and higher top speed are about the same. This

Figure 5.—Effect of Increased Maximum Speed on Trip Time



SOURCE Jack Smith, Office of Technology Assessment contractor report. Data derived from Information on acceleration/deceleration rates, British Rail Research Department, SNCF.

raises the difficult question of what should be the planned top speed of the rail link. Most rail lines are likely to have less than 100-mile intervals between stations. For example, between New York and Washington, there are, on average, major stations at 45-mile intervals. Only four trains a day each way run 90 miles nonstop (Philadelphia to New York). In these cases, the intermediate stations have the best overall trip times from high frequency trains at maximum 120 mph. However, major long-distance flows achieve greater benefit from higher top speeds.

Fares

Fare is the most complex of the factors the rider considers, but it is a fundamental determinant of demand and the financial viability of any public mode of transportation. Figure 7 illustrates the range of current rail fares and perceived marginal automobile costs, including access and parking costs.

At the shorter distances, the price of travel by public mode is most often measured against the perceived marginal cost of the automobile, except in cases where an automobile is not an available alternative. It is sometimes argued that intercity automobile trip costs should include maintenance, tire wear, and even depreciation and interest on capital. However, intercity trips in competition with public modes are normally only a tiny fraction of the trips made by automobile; only on rare occasions is intercity use part of the justification for purchase of an automobile. Maintenance and tire wear both have an element related to total mileage, but are small, and in most cases are not included by riders in cost calculations. Thus, for the rider, the calculation of trip cost by automobile normally includes gasoline, parking, and tolls, if any. This cost is then divided by the number of persons in the automobile. A cost of perhaps 10 cents per mile becomes 2½ cents per mile for four riders. Party size, therefore, is a major factor in its own right. The typical automobile load factor for intercity trips is 1.6 passengers per vehicle, which means that probably less than 40 percent of automobile riders travel alone. To compete in a market where the dominant mode (automobile) has a competitive price that can vary widely with party size requires very sophisticated fare policies on the part of the operators of public modes of transportation.

Political or social objectives can alter the competitive position. For example, the French Government pays French National Railways (SNCF) a large annual sum to provide cheaper fares for children, the elderly, and socially disadvantaged groups. This payment is calculated as the difference between the fare charged by SNCF to these groups and the standard fare. Other railroads such as British Railways (BR) and Amtrak provide such reduced fares as a matter of commercial judgment to widen the market covered.

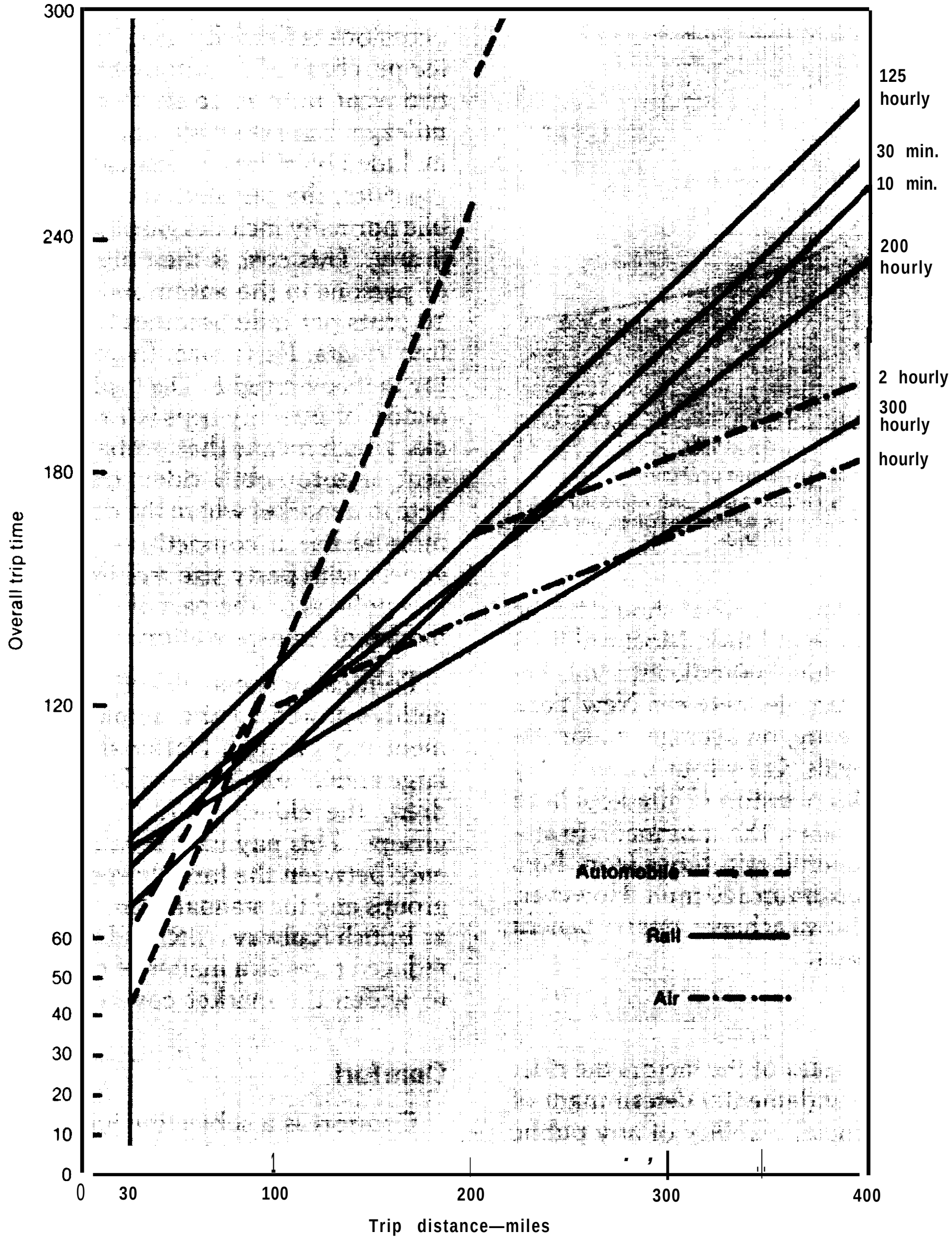
Comfort

Comfort is a subjective judgment. For the rail mode, it involves the travel environment—seating, company, catering facilities, relaxation, and ability to read, work, or sleep. While other modes offer comfort in seating and environment, flying, or driving or riding in an automobile all present added anxieties. Food choice will be more limited on short-haul flights and an automobile trip will require stops.

Convenience

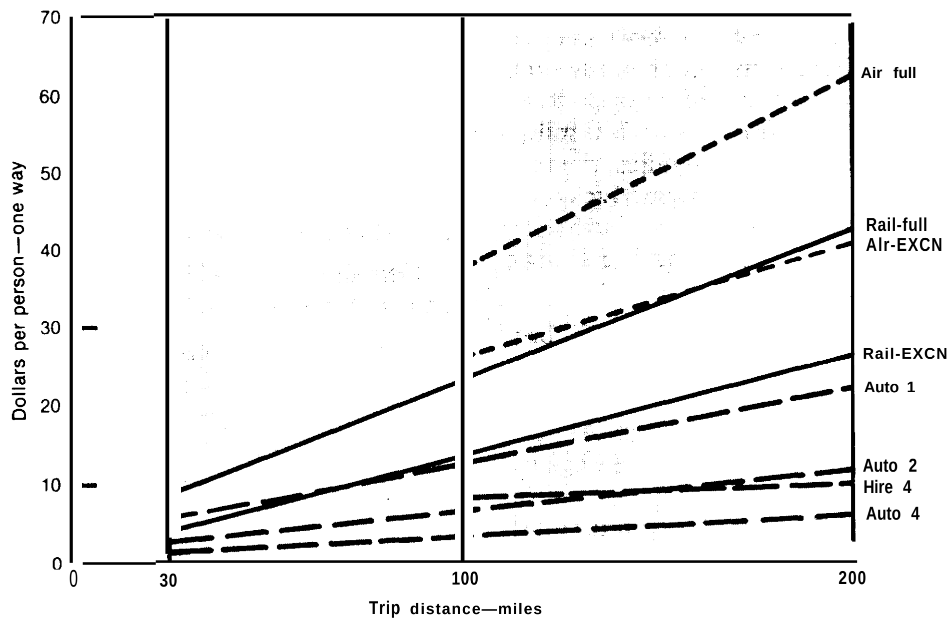
Auto travel, with its infinite choice of starting times, is far more convenient than public modes

Figure 6.—Effect of Distance and Mode: Nonstop Trips Up to 400 Miles



SOURCE: Jack Smith, Office of Technology Assessment contractor report

Figure 7.—0ne-Way Fare-Price in Dollars per Person (includes access/parking)



SOURCE: Jack Smith, Off Ice of Technology Assessment contractor report. Data compiled from modal fare comparisons using the following assumptions automobile— 10¢/mile plus $2.50 parking; train — N EC Am fleet fares, air— Los Angeles-San Diego and New York-Washington.

with limited service frequencies. With auto travel, changes in itinerary can be made at any suitable time, and luggage handling is minimal.

Public modes always involve transfer, which is inconvenient and time-consuming. Some travel modes allow an elapsed time of up to 40 minutes as the perceived time equivalent to the inconvenience factor of having to change from one mode to another. Even where arrangements are made to handle luggage at terminals, public transportation cannot match the convenience of the automobile which moves large quantities of baggage from origin to destination without any intermediate handling.

Market Sectors

Major purposes for intercity travel are business, family, and other private travel. For each of these trip purposes, the factors discussed above have different relative values. The business traveler places a high value on time and will pay for comfort and convenience. Thus, fare is often less important than trip time, frequency, comfort, or convenience. At the other end of the spectrum are riders for whom the cost of the trip is paramount. For example, a family of four would calculate the cost of a 200-mile round trip by automobile at perhaps $26 ($20 gasoline plus $6 parking or $6.5o per person). The family would find unacceptable the standard rail fare of about $100 plus access costs (over $25 per person). Even a total round-trip fare of $70 for a family of four would be only nominally more attractive.

Between these extremes are other groups traveling on personal business or for leisure and recreation. The public modes become more attractive to the extent that riders travel alone, value time more than money, or find the convenience of rail preferable in major cities where auto congestion and parking are difficult in downtown areas. Much of such travel is commuter, traditionally at cheap fares, and by nature confined to peak periods or to special events. Public modes can capture sizable shares of these markets only by incurring high peak costs, and such market penetration requires low fares to offset the advantage of a multiple-occupancy automobile.

Figure 7 shows the present pattern of rail, air fares, and automobile cost. The rail round-trip excursion fare is at about the level of cost of an automobile used by only one person. Multiple use brings automobile costs substantially below rail fare. Thus, for trips where two or more people travel together, some further reduction in rail fare may well be needed, even where rail is competitive on trip time, for example, for trips of 100 miles or more. At distances less than 100 miles, the rail mode becomes progressively less attractive compared with automobiles in multiple use, since rail travel is slower, more expensive, and less convenient in many cases.

Air fares have fluctuated widely recently, but figure 7 shows a typical situation where excursion discounts of up to perhaps 30 percent are offered for certain times of the day or week. At present fare levels, rail has a clear fare advantage to offset any time disadvantage. Any move to raise fares on high-speed rail to increase revenue could erode the differential between rail and air fares. However, for the business market, higher rail fares should be possible if rail trip time is brought significantly nearer to air. Rail fares need to distinguish between the air and auto markets by time of day and duration of stay if rail is to have maximum ridership and revenue. At 100 and 300 miles, competition exists between air and automobile, with rail having a slower overall trip than either. Those individuals who now prefer the automobile have had the option of a faster, more expensive air mode, but did not take it. For this group, the costs and the convenience of the automobile have priority over speed at the longer distances. High-speed rail would offer a speed advantage, and a smaller fare differential, than the existing air mode. The likelihood of attracting automobile users to the new rail mode will depend on the level of fare that can be offered, and on whether use of these fares can be protected against penetration from the business sector, which is carried by rail at higher fares.

In each of the market sectors, there is an interaction between fare and ridership, as well as between trip time and ridership. Selective fare reductions to achieve high market success will have the effect of reducing the average fare per mile (the "fares yield"). Where trip times are relatively close, rail can offer a fare approaching the air fare (although in self defense the airlines could reduce fares), but substantial penetration of the automobile sector, or generation of new travel, will take place only at much lower fares. It maybe unwise for rail planners to expect the overall rail fare to be higher than it is now; it may have to be lower to generate the required level of travel and, in some cases, to realize the maximum cost to revenue ratio.

Methods of Evaluating Future Demand

Demand for travel by any mode (including rail) can be forecast in either of two ways:

1. by predicting directly the future of the mode in question, taking into account its relationship with other modes; or
2. by first predicting the future level of all intercity travel and then determining the share likely to fall to the mode in question.

Regardless of the approach taken, the task of trying to forecast the demand for a particular mode, or even travel in general, is a difficult one. The process by which the public chooses between competing modes for any particular trip is complex, and changes in the price, speed, or frequency of one or more modes may alter their relative attractiveness. Computer models have been used to develop forecasts of travel demand. However, for prediction of intercity demand for high-speed rail, such models have been adversely affected by the paucity of good data on automobile travel. For most U.S. corridors, the rail demand data are available only for the currently limited train service. The present service is offered at speeds lower than those envisioned for high-speed service. Thus, models may have limitations in predicting ridership, which is clearly critical to predicting accurately the economic potential of a proposed rail system.

High-speed rail is an intercity mass transit mode requiring high frequencies to be attractive. Table 10 is a matrix of frequency, train size, and capacity showing one possible calculation of annual ridership. In table 10 an average load factor of 60 percent has been assumed for rail, which is above the present Shinkansen level of 53 percent, and probably is as high as can be expected even under favorable circumstances in the United States. The load factor used in the table is translated into ridership on the assumption that the average trip

Table 10.—60 Percent of Maximum Round-Trip Capacity[a] (In millions per year)

Size of train		Frequency		
Cars	Seats	Hourly	30 min.	10 min.
3	200	3	5	16
7	500	7	13	40
14	1,000	13	26	79

[a] Assumes average trip length is one-half route length. Assumes service for 16 hours per day.

SOURCE: Office of Technology Assessment.

is about half the length of the route, which is roughly equal to the travel distance for the upgraded NEC and not quite as high as Shinkansen experience.

Cost Analysis of High-Speed Rail

Basically, there are two categories of costs:

- capital costs (the costs of assembling and constructing the infrastructure), and
- operating costs (the costs of running the system once it has been constructed):

Capital Investment Costs

Capital costs for new high-speed railways comprises several elements:

- Land acquisition. —Land acquisition cost generally is lower in rural and desert areas than in urbanized areas.
- *Terrain.—On* relatively flat, unobstructed terrain, a new line can be built without major excavation, or viaduct and tunnel construction. In such circumstances, costs will be lowest, although still substantially more than using existing right-of-way.

  On the other hand, it is very expensive to construct embankments and to cut through hillsides to make acceptable gradients, and even more expensive where long viaducts and tunnels are needed. The costs for this work will increase with the maximum speed planned. As speed increases, the acceptable curve radius will increase. This, in turn, increases the need to cut through the natural features of the terrain rather than avoiding them.

  Also, environmental problems may have a substantial effect on construction cost—if, for example, tunneling is needed to avoid exposure in sensitive areas, or if diversion is needed to avoid residential areas or areas of natural beauty.
- *Urban areas.* —Construction in urban areas would be difficult without powers of eminent domain. In addition to the cost of land required for the right-of-way, it may be necessary to purchase land and buildings likely to be affected environmentally. Road crossings are a major cost item, and the track may have to be sunk below ground level for environmental reasons.

  New construction in urban areas therefore generally will be the most expensive and difficult to achieve.
- *Buildings and facilities.* —Using existing facilities avoids capital costs for stations, parking, and service facilities. For new construction, the very substantial costs of these items are inevitable, and, in addition, operating costs may be higher because sharing with other operations on routes will not be possible. Where the new route becomes part of an existing network, much of the cost of new buildings and facilities can be avoided.
- *Use of existing track.—Where* an existing railway route is available and suitable for high-speed rail, construction costs will be minimized by using it. However, major realinement of tracks to improve speed can be very expensive and may approach the cost of new construction.

Thus, the options for high-speed railway are, in ascending cost order:

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1. use existing right-of-way where suitable, with minimum upgrading (BR—$2½ million per mile);*
2. use existing right-of-way with major upgrading (NEC—$4.5 million to $6 million per mile);
3. construct new right-of-way for inexpensive sectors (SNCF—$4 million per mile);
4. construct completely new right-of-way (JNR–$20 million to $40 million per mile).[2]

Operating Costs

Operating costs can vary considerably depending on track, equipment technology options, and operating conditions in a given corridor, including service frequencies and equipment utilization. Higher levels of service frequency and equipment use should result in lower unit operating costs. For the purposes of simplicity, there are three basic operating cost components: "over the road" operating costs, maintenance of equipment, and maintenance of track. The discussion of these costs that follows is based on steel-wheel on steel rail technology. Magnetic levitation (maglev) is not a technology with a history of revenue service operation. However, manufacturers have suggested that track and equipment maintenance costs promise to be lower for maglev because of friction-free operation and reduction in the number of moving parts.

Equipment maintenance costs naturally are dependent on the type of equipment operated. Electric-powered trains have inherently lower maintenance costs than diesel units. Within a given category of propulsion, operating costs will differ somewhat according to the basic equipment design and construction. Tilt-body equipment, for example, would require more maintenance than nontilting equipment. Equipment utilization depends on the number of train sets required to provide service, the length of the corridor, the schedule, and the required maintenance cycle. Labor agreements and productivity levels also will affect equipment maintenance costs.

*British Rail data extrapolated for U.S. track conditions for a Michigan corridor. Cost per mile will vary with the corridor.

[2]JNR costs are likely to be the maximum due to rugged terrain and congested city areas encountered in building its lines. Elsewhere costs could be cheaper.

A number of variables similarly influence track maintenance costs. These variables include equipment weight, ride characteristics, springs, and wheel profiles. Another important variable is track technology and the relation between it and the vehicles to be operated. Elements of track design include the use of cross ties or slab track construction. The design and formulation of the rail itself is another influence. The most successful systems have designed the track and trains as a unified system. Both the French and British high-speed trains have been designed to run at much higher top speeds than the trains they replaced without adding to the level of track wear. Specific corridor conditions also have an effect on railbed maintenance costs. These include climate, type of subgrade material, and the nature of the alinement selected (e.g., number and extent of curves).

Track maintenance costs also depend on vehicle weight and on unsuspended mass. Heavier trains place greater stress on the track structure. Consequently, maintenance requirements are greater. Variation in equipment design is the principle component of vehicle weight. If higher speeds are to be achieved with locomotive hauled trains, lighter axle loading is necessary. Some high-speed rail systems have managed successfully to reduce track maintenance costs by locating several power units within each train for more uniform, lower axle loadings. Trains also have been designed so that adjacent cars share a single set of axles. Maintenance-of-way costs also depend somewhat on the type of motive power used. In U.S. experience, electric trains generally weigh less than diesel-powered trains and, therefore, require less track maintenance. However, there are design differences. For example, French trains have been designed specifically with low axle loadings in mind and weigh less than the Shinkansen trains.

Direct operating costs associated with actual "over-the-road" operations such as energy, depend on several variables noted earlier; namely, type of propulsion and equipment design, operating speeds, and the specific corridor alinement. Lightweight trains offer lower energy consumption rates. Corridors with low gradients and few curves similarly offer the optimum conditions for low energy costs. Perhaps the most important component of "over-the-road" costs is that associated with labor. Here, costs will depend on such factors as the number of workers required to operate a given train, the basis and rates of pay (hourly v. mileage rates), and the need to change crews.[3]

[3]Information on operating costs was provided by Gordon Peters, Chief, Rail Marketing, New York State Department of Transportation.

Chapter 4
SOCIAL AND INSTITUTIONAL FACTORS

Contents

Chapter 4
SOCIAL AND INSTITUTIONAL FACTORS

Considerations other than economic efficiency also must be taken into account in a decision to construct high-speed rail. This chapter discusses the social and institutional factors likely to influence decisions on potential high-speed rail corridors in the United States. Following is a brief summary of the main points made in this chapter.

SUMMARY

Given the uncertainties surrounding the ability of high-speed passenger rail to pay for itself from operating revenues, its introduction into any U.S. corridors probably will hinge on whether the projected public long-term benefits are sufficient to justify governmental support. Short-term benefits, such as employment during construction, typically will accrue to developers and will occur irrespective of ridership levels achieved by the system.

The public benefits often cited for high-speed rail service include: increased mobility, reduced highway and airport ground congestion, energy efficiency and security, and economic development and employment. In addition to these explicit reasons, national pride and a desire for continued and updated rail service also are reasons that appear to influence public opinion in favor of high-speed services. "If other countries can provide such service successfully, then why can't the United States?" is a question frequently raised.

However, as indicated elsewhere in this report, foreign high-speed rail systems typically were implemented in densely populated corridors, and, in France and Japan, along corridors where existing capacity had been reached.

Costs to be considered are not solely economic in character but include environmental concerns, adverse effects on competing modes and services, and questions of regional equity.

Some benefits cited can be quantified. Others are a matter of subjective judgment. Some costs, particularly those associated with economic efficiency of the system can be projected, while others are more difficult to quantify. Some claimed benefits, such as energy efficiency and reduction in highway and airport congestion, when taken individually appear marginal. However, when all benefits, tangible and intangible, are taken into account, a given region or locality may well wish to implement a high-speed system—be it rail or magnetic levitation (maglev). With the exception of improved mobility, all factors cited as long-term benefits for a high-speed system will be contingent on the actual ridership a system attracts. Short-term benefits, such as employment during construction, typically will accrue to developers and will occur irrespective of ridership levels achieved by the system.

The social costs of introducing high-speed rail service may be high. If the venture cannot pay for itself, continual subsidies in addition to high capital costs may be required. If a system is to be federally subsidized, political disputes may well occur over which State should host it, and at issue would be the appropriate criteria for selection of a site.

The need to work out some sort of joint use or lease/purchase agreement with existing private railroads is a prerequisite to the implementation of any high-speed rail project using existing track. Because of the high construction costs for an entirely new right-of-way, it could be very advantageous, where possible, to use existing rights-of-way. With the exception of the Northeast Corridor (NEC) and several isolated segments elsewhere, however, all railroad rights-of-way are privately owned.

The National Railroad Passenger Corp. (Amtrak) has statutory authority to provide intercity passenger rail service in the United States. Therefore, licensing agreements must be reached before

any private company can begin intercity rail service over Amtrak routes. Amtrak has indicated that it does not view high-speed service as a substitute for its own passenger service. Thus, Amtrak intends to continue operating in corridors where high-speed service could exist and expects to be reimbursed for any operating losses attributable to competition lost to the high-speed rail service. However, some questions have been raised regarding Amtrak's statutory authority and the applicability of licensing in those corridors where Amtrak service is not presently provided.

If high-speed intercity service is provided in the United States, existing equipment specifications and track standards will require revision to incorporate speed, weight, and design modifications. Questions concerning shared v. dedicated rights-of-way will have to be resolved.

SOCIAL FACTORS

Public Sentiment Favoring Modern Rail Services

Polls reveal that a majority of Americans wish to preserve rail service as a transportation option, even when subsidy is required.[1] Some advocates of high-speed rail in this country regard it as a matter of national pride. "If other industrialized nations can afford to have high-speed rail travel, why can't the United States?" they ask. Those who believe that our country's status as the technological world leader should be preserved and promoted may well support the introduction of high-speed rail. Others question whether implementation of rail, considered by many as a mature technology, is advisable.

Energy Savings Considerations

The energy crisis that emerged in 1973 triggered many efforts to curb the Nation's use of petroleum resources and to lessen dependence on foreign oil. Among the alternatives examined was upgrading intercity rail service to higher speeds so that, as fuel prices continued to increase, travelers increasingly would turn to rail and reduce less fuel-efficient automobile travel.

As required by section 1003 of the Rail Passenger Service Act, the U.S. Department of Transportation (DOT) and Amtrak made estimates of the degree to which ridership might increase if fuel prices increased significantly and train service were improved substantially. Although projections indicated that ridership would increase under these circumstances, DOT's overall conclusion was that "energy impacts of rail corridor development are at best insignificant."[2] Although Amtrak believed the energy savings would be much higher than DOT estimated, it agreed that any energy savings were an incidental benefit of corridor service and could not serve as the sole or major justification for upgrading service.[3]

Any significant energy savings are likely to occur only if substantial displacement of automobile use occurs which means current U.S. transportation patterns would have to change.

Increased Mobility and Transport Alternatives

Increased mobility and improved transport system capacity are important reasons for implementing high-speed rail, particularly in regions of the country experiencing population growth.

As discussed in other chapters, high ridership levels are made possible by the capacities typically offered by high-speed trains with frequent service. For example, the original Tokyo-Osaka line attracted *85* million riders in 1970. The total line, extending from Tokyo to Hakata attracted a high ridership in 1975 of 157 million passengers.

[1] Louis Harris & Associates, "The Continuing Mandate to Improve Intercity Rail Passenger Travel," summary, for Amtrak, 1978.

[2] Federal Railroad Administration and National Railroad Passenger Corp., *Rail Passenger Corridors, Final Evaluation* (Washington, D. C.: U.S. Department of Transportation, April 1981), transmittal letter to The Hon. George Bush, President of the Senate, from Drew Lewis, Secretary of Transportation.

[3] Ibid.

In the United States the market for intercity passenger rail has been eroded by the introduction and extensive use of air and automobile technologies. If rail is to attract the ridership necessary to sustain at least operating costs at the very minimum, it must compete with other transport modes in the private sectors. Some would argue that the loss of ridership and the potential service losses of these other modes, were high-speed rail to be successful, should be considered a public cost, particularly if the new rail service receives Government support. Others argue that other modes are already subsidized, and rail deserves parity in treatment. While rail proponents strongly disagree with the report, a recent analysis by the Congressional Budget Office indicates that for 1978, "the federal government spent $2.50 for each dollar collected in fares or state and local subsidies for passenger rail service. By comparison, for each $1.00 that motorists or air travelers spent, the federal government spent 0.2 cents and 5.o cents, respectively. "[4]

Crucial to evaluating increased mobility are answers to questions related to: What are near- and long-term transport systems capacities and needs for a given region? What are the likely tradeoffs among transport options? Are conditions on a corridor such that people would use the rail system if implemented?

Recently, high-speed rail has been proposed in corridors where current heavy use is straining capacity of intercity highways, where long-term additional capacity needs are foreseen, and where the building of additional highways runs up against land-use or availability constraints. The extent to which high-speed rail could be expected to alleviate highway congestion depends on the following factors:

- the degree to which the congestion is or will remain unsolvable by other means,
- the degree to which automobile drivers will choose to ride the train to avoid the highway,
- the degree to which there is room to install high-speed rail, and
- the degree to which it may provide service to potentially offset long-term capacity needs for a region.

To evaluate these factors, current traffic patterns and future alternatives must be understood first. Studies indicate that congestion on the Interstate Highway Systems results more from commuter traffic than from intercity travel. Therefore, the issue is whether commuters making relatively short daily trips could be induced to use high-speed rail for commuting, whether the corridor service is convenient for other urban area trips and whether high-speed trains are the appropriate technology for such a service. Current U.S. intercity rail service typically is not designed as a commuter or transit system. Studies and experiments by transit agencies trying to woo commuters show that most people will discontinue using their automobile only under severe parking restriations. [5] Some rail proponents now suggest that the trend toward longer term ownership and use of older vehicles may begin to alter people's choices for intercity travel modes.

To evaluate the impact of high-speed rail on long-term capacity and congestion problems, answers are required to the following questions: What is the projected population growth of the area? What regional plans exist for development of the area, and to what extent are the long-term transportation options being evaluated? What factors are likely to shift that would encourage eventual diversion to any proposed rail system?

Other questions regarding tradeoffs between highway and rail include: How many drivers use the highway to make the full intercity trip? Would drivers be willing to pay more to arrive at their destination quicker (recognizing that, if so, they might prefer taking the plane)? Would the station location and transit service availability at their destination affect their decision? Is high-speed rail an appropriate application of technology to alleviate commuter or urban congestion?

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[4] "Federal Subsidies for Rail Passenger Service: An Assessment of Amtrak" (Washington, D. C.: U.S. Congress, Congressional Budget Office, July 1982), p. 13.

[5] OECD Road Research Group, *Road Research, Transport Choices for Urban Passenger (Measures and Models)* (Paris: Organisation for Economic Cooperation and Development, September 1980).

Alleviating Airport Congestion

High-speed rail also has been proposed for corridors where heavy demand is straining airport ground capacity. The extent to which high-speed rail would alleviate this type of airport congestion depends on several factors:

- the degree to which the high-speed rail route matches the destinations of air travelers,
- the degree to which the congestion is unsolvable by other means, and
- the degree to which air travelers can be induced to select the train over the airplane.

In the early 1970's, a major argument for high-speed rail in the NEC was that-New York City could avoid building a fourth airport, which at the time appeared inevitable. Yet today, even though the NEC still does not permit high-speed rail service of the sort then contemplated, New York City is no longer seeking to build a fourth airport. The prognosis changed because: 1) New York's forecasted growth in air travel did not materialize, 2) larger planes and more efficient air traffic control systems allowed the existing airports to handle more traffic without building new facilities, and 3) the problems of finding a suitable airport site proved more difficult than planners imagined.

With the exception of the NEC and southern California, it does not appear that high-speed rail service would have an appreciable effect on airport ground congestion. The travel patterns for other large hub airports that now have, or are soon expected to have, severe congestion (e.g., Chicago's O'Hare, Atlanta's Hartsfield, and Denver's Stapleton) are not such that high-speed rail would be an appropriate substitute for air. These airports are served by a hub-and-spoke pattern of air routes, and much of the congestion results from passengers transferring between flights. High-speed rail, which works best when there is a high volume of origin-destination traffic along a corridor, would not compete effectively in most hub-and-spoke markets.[6] If an airport is to also serve as a high-speed rail station, frequency of service from the airport must be a major consideration.

[6] *Airport and Air Traffic Control System* (Washington, D. C.: U.S. Congress, Office of Technology Assessment, OTA-STI-175, January 1982).

Promotion of Tourism

Regions of the country where tourism is vital to the economy are looking at high-speed rail for two reasons:

1. to maintain access for tourists should other forms of transportation become constrained, and
2. to increase tourist travel by building a high-speed rail system so technologically advanced that the rail trip itself will serve as an attraction and inducement.

Whether high-speed rail itself can lure additional tourists to a given location is uncertain. Estimating the degree to which technology may induce demand is difficult since it is not always possible to predict with certainty the desires of tourists. Understanding how and why tourists currently come to the location in question, together with surveys to determine the likelihood of their using high-speed rail or other advanced ground technologies, would contribute to the analysis. Typically, tourists prefer to travel by car because they wish to visit widely scattered sights, and, families frequently travel with much luggage. The auto provides flexibility not offered by public modes of transportation.

Regional Development

High-speed rail systems also are being proposed on the grounds that they would stimulate economic development and employment in a region, generating new development along the route as did the Erie Canal and the railroads in the 19th century. Historically, regional development has followed new transportation development because transportation provided a new, more efficient means of reaching an area. Questions concerning high-speed rail include whether it meets a need that is not already being met and whether this need is significant enough to bring about the sort of economic development contemplated by proposers. At best, quantification of regional impact in terms of employment or development will be difficult. However, proponent's consider such development a strong reason for implementing high-speed rail systems. While economic development might occur, tradeoffs such as high-speed rail competition with air, automobile, and bus for passengers must also be examined. The regional benefits of economic development around a corridor must be analyzed against the possibility that the region or Nation eventually may have to support operating losses if the rail system does not prove profitable or if ridership levels projected do not materialize.

Passenger Safety and Comfort

If high-speed rail or maglev were to be introduced in the United States, certain existing regulations regarding passenger safety and comfort would need review, and certification of new technologies would be necessary. The following is a brief discussion of the regulatory questions which would need to be addressed.

Speed Limits

Currently the only high-speed trains (120 mph or more) in the United States, operate on sections of the NEC. Elsewhere, speed limits are generally 79 mph; speeds of 90 mph are permitted on small sections of track, and New York State now has trains operating at 110 mph on portions of its rail network. On many lines, lower speeds often are in effect because of track conditions or traffic mix. Limitations on speed usually are set for safety reasons. Restrictions on speed of passenger trains through curves is also based on passenger comfort, although the trains themselves could negotiate the curves safely at higher speeds. Speed limitations that would affect implementation of high-speed rail cover such items as track conditions, signaling requirements, and maximum speed through curves.

Track Conditions. —Federal Railroad Administration (FRA) track safety standards specify that the maximum allowable operating speed for passenger trains is 110 mph on Class 6 track, * and lower speed must be observed on track of lower categories. Both French National Railways (SNCF) and British Railways (BR) have trains designed to run safely at much higher speeds on track designed originally for 100-mph operation.

France's TGV has a technical design speed approaching 200 mph, and BR says that its high-speed trains and advanced passenger trains could operate safely at 150 mph. Japan can operate its equipment at 160 mph. In any case, the U.S. signaling requirements change according to the maximum speeds permitted.

Signaling Requirements. -FRA's existing signaling requirements limit train speed to 79 mph unless signals are displayed in the engineman's cab or intermittent inductive train stop equipment is in use. Some experts believe that above 125 mph, fully automatic train control should be part of the signaling system. Fully automatic control causes problems where high-speed passenger, commuter, and freight trains of widely different braking characteristics use the same tracks. BR and SNCF have increased the train speed for a given signal spacing by using more sophisticated braking systems, which can reduce the distance required to stop the train. New York State has petitioned FRA to review its signaling requirements for purposes of upgrading speeds to 90 or 95 mph on certain track segments. This matter is pending, although an earlier request for complete review of cab signaling requirements was denied.

Maximum Speed Through Curves. -Speed limits through curves depend on the radius of curvature and the superelevation of the outer rail. When a train negotiates a curve, centrifugal force causes more of the total weight to be transferred onto the outer rail, and passengers are pulled toward the side of the seat nearer the outside of the curve. Thus, speed through curves is determined by the need to avoid or mitigate the following:

- outward weight shifts that could cause the vehicles overturn;
- overload on the outer rail so that it is displaced, and the train derails;
- discomfort to the passengers from excessive centrifugal forces; and
- maintenance costs caused by these forces on the rail.

The lateral component of centrifugal force can be reduced by banking the track (superelevation). Very high superelevation (as on auto racetracks) would permit much higher speeds for passenger

• Class 6 track is defined as "a track that meets all of the requirements prescribed in Part 213 (Track Safety Standards, Code of Federal Regulations, 49 Transportation), with a maximum allowable operating speed for passenger trains of 110 mph."

trains; however, if the track is also used for heavy, slow-moving freight trains, the weight of the train on the inner rail would be excessive and rapid wear and damage would result. Thus, superelevation in the United States is limited by Federal regulation to 6 inches. *

Safety and Strength Requirements of Passenger Equipment

Concerned about the possibility of collisions among dissimilar types of equipment, U.S. practice is to prescribe vehicle strengths for passenger equipment that are higher than those in Europe. As a result, U.S. passenger railcars are far heavier. Power requirements to move these heavier vehicles are correspondingly greater as is wear on the track. European rail practice suggests that the U.S. specifications used for railcar equipment strength may, in fact, be counterproductive in a collision. Data to support the European experience were not analyzed for this report. However, such practices as well as energy savings from lighter weight equipment might well be investigated for possible adoption in the United States. Questions of shared v. dedicated rights-of-way no doubt would be raised in the context of this issue assuming that heavier freight equipment would be operated on the same line with the new, lighter weight designs in passenger equipment.

*The speed through a curve at which the passenger feels no lateral forces (the "balancing speed") is calculated by the following formula:

$$V = \sqrt{\frac{Ea}{0.007D}}$$

where V = balancing speed (miles per hour)
Ea = actual elevation of the outside rail (inches)
D = digress of curvature

Passenger trains generally travel around curves at speeds higher than the balancing speed. Most foreign railroads permit a passenger train to travel around a curve at a speed as though superelevation were 6 inches higher than actual ("6 inches of unbalanced superelevation"). The formula then becomes:

$$V\ max = \sqrt{\frac{Ea + 6}{0.0007D}}$$

In the United States, Federal regulations limit the speed of trains through curves to 3 inches of unbalanced superelevation. The formula is:

$$V\ max = \sqrt{\frac{Ea + 3}{0.0007D}}$$

This limitation, however, is based on comfort rather than safety criteria: witness the fact that foreign trains successfully negotiate curves with 6 inches of unbalanced superelevation. The regulation thus means that U.S. passenger trains are required to slow down expressly for curves and thus lose running time (Steve Ditmeyer, Chief of Research, Burlington Northern Railroad).

Safety Issues at the Highway/Rail Interface (Grade Crossings)

For safety reasons, any proposed high-speed system should avoid crossing highways at grade level. Grade crossing fatalities, though declining, represent the highest fatality category for rail in the United States.[7] (In Europe, however, French and British trains traveling at 100 to 125 mph routinely cross highways at grade with gates, warning sounds, and closed circuit television.) New York State has some nongrade separated rail crossings with special sensors for warning automobile traffic of approaching trains. Location of the grade crossing and type of equipment may dictate optimum grade crossing systems for high-speed rails. Rail grade crossings may represent a significant public concern in any implementation plan for a high-speed system, according to State transportation officials.

Safety Certification of High-Speed Rail Technology for Operational Use

For the most part, high-speed rail technology consists of tried and tested "off-the-shelf" technology. Two exceptions, which require separate consideration, are tilt-body equipment and maglev.

Tilt-body equipment, in varying degrees, is an important feature of the British, Canadian, Swiss, Italian, and Swedish efforts to develop high-speed rail systems. The tilt-body is intended to enable trains to travel faster through curves without sacrificing passenger comfort. The car "tilts" to counteract centrifugal force and maintain passenger comfort while the train traverses curves at high-speeds. Not all tilt-body equipment has been tested on an operational basis. At present none of the tilt-body developments is free from technical problems. There have yet to be satisfactory commercial ventures due to high maintenance costs. Use in this country-if operational and economic feasibility is proved-will depend on relax-

[7] *An Evaluation of Railroad Safety* (Washington, D. C.: U.S. Congress, Office of Technology Assessment, OTA-T-61, May 1978).

ation of the 3-inch unbalance rule and standards set for equipment reliability, safety, and comfort.

Maglev for high-speed operation is so new that it has yet to be proved to be an operational large-scale people mover for revenue service. Developers and prospective buyers are beginning to raise questions about which U.S. Government institutions should certify the systems and when they should be certified.

As indicated in previous chapters, maglev systems are being developed in West Germany and Japan. Because of differences in the technology, the West German system is further along in development than the Japanese. Tests of the West German system are scheduled to begin in 1983 at the West German Emsland Test Facility in Lower Saxony. At the earliest, results are projected to be available in late 1985. However, in light of ongoing. development efforts in both countries it may be prudent for U.S. transportation agencies to remain as informed as possible about the technology status.

Environmental Concerns

Land Use: Assembling Rights-of-Way

For purposes of this report, high-speed rail has been defined as trains that travel at 125 mph or greater. While it is possible (by substantially limiting freight travel), to mix freight with passenger trains traveling at this rate of speed, high-speed rail is often likely to involve separate dedicated tracks, if not dedicated rights-of-way. Freight traffic aside, high-speed rail could be instituted on existing U.S. rights-of-way, although most corridors would require modification including upgrading of track, elimination of existing curves, and signaling improvements. Reaction of public and private groups to proposals to do so will depend on the impacts, benefits, and costs of the changes that have to be made. Land-use issues would be subject to negotiation.

Proposals calling for the construction of entirely new rights-of-way, or for any transportation alternative, will require public agreement on land-use questions. The degree to which local governments, institutions, environmentalists, individuals, or other citizen groups will support the implementation of high-speed rail probably will be influenced by projections of demand for the service, by the amount of urban land and areas of natural beauty through which the line must travel, and by the perceived need to reduce congestion elsewhere. These basic concerns will not differ among most transportation alternatives studied.

The French avoided high capital costs and environmental opposition in building the TGV by using the existing line into and out of Paris. The population density of Western Europe indicates that the problems of building a new rail line between Paris-Lyon were made much easier by the relatively low density of population between the cities. In England, and elsewhere in Europe, choosing an acceptable alinement would be exceedingly difficult, if not impossible. In the United States, the NEC and portions of Los Angeles are as densely populated as much of England; Ohio and Florida are more similar to France (but without any cities on the Paris scale of population); Nevada has a far lower populaton density than anywhere in Europe.

In sum, assembly of urban land parcels in a line sufficiently straight to permit genuine high-speed rail service is a legally complicated and costly undertaking. The irony of the land-use issue is that high-speed rail promises to be most successful in corridors where there are many people to ride it, yet these very same densities make the establishment of new high-speed rail lines exceedingly difficult and costly.

Noise, Vibration, and Visual Barriers

Japan's bullet train, in operation nearly 20 years, initially produced severe noise and vibration due to the materials used in track construction. These problems have been mitigated for the most part by cushioning tracks on viaducts and erecting sound proof barriers along the right of way. The extent to which such problems exist and the measures necessary to satisfy residents of large urban areas through which the train would go probably depend on the type of high-speed rail system in question and the measures taken to overcome any problems. The noise generated by various rail systems tends to differ slightly due to the way it is measured.[8]

Any train traveling at high speed will induce vibrations, particularly on viaducts and bridges. Maglev systems are theoretically quieter than high-speed rail. Noise levels of the West German maglev will be tested at Emsland.

In addition to noise, visual effects of viaducts and elevated track may also raise environmental concern and affect route designation. However, any transportation alternative is going to raise environmental questions, and the strength of specific environmental objections cannot be known without analysis on a corridor-specific basis.

[8]Current noise measurements for selected systems indicate the following:
- Amtrak AEM7 locomotives @ 108 mph —89dB @ 100 ft from track,
- TGV @ 160 mph—95 dB @ 82 ft from track, and
- Japanese National Railways (JNR) (on embankment) @ 130 mph—85 dB @ 62 ft from track.

Amtrak Specification #NL 77-8, IPEEP Report on SNCF, JNR Staff.

INSTITUTIONAL FACTORS

Amtrak

Amtrak currently has statutory authority to provide intercity passenger rail service in the United States.[9] Although some questions exist about whether such authority extends only to routes over which Amtrak trains now operate or to any proposed route, implementation of high-speed passenger rail today cannot be accomplished without prior agreement with Amtrak.[10] If Amtrak is not the operator of the proposed high-speed system, a number of institutional questions must be addressed. Will high-speed service conflict with any Amtrak trains? How would a competing system affect Amtrak's finances? Would the existence of profitable high-speed rail service in the United States put pressure on Amtrak to provide high-speed rail service in the corridors it serves, and what would the effect be?

Private Railroad Companies

A second institutional consideration is that most railroad track in America is owned by private railroads. Introducing high-speed rail in most corridors, therefore, would require some sort of lease/purchase agreement with existing owners. If the high-speed system requires a dedicated track, acquisition of an existing right-of-way may hinge on whether there is a practical alternative route to handle the freight now being carried on the line. Competitive reasons may also severely limit the degree to which private railroads would share their freight lines. It is possible, however, to work out some agreements. In some cases, lightly used or abandoned lines for the high-speed rail rights-of-way may provide an alternative to be explored. New York State, as an example, upgraded lightly used Conrail line from Class 4* to Class 6 at a cost of about $200,000 a mile.[11]

Local Governments

Where construction of a high-speed rail system can be shown to attract enough ridership, site-specific concerns will have to be taken into account by local governments as well as developers. For example, to make best use of their high-speed, trains should not make frequent stops. Local governments may base decisions to compete for a stop on whether the system is expected to be self-sufficient, whether demands will be made on them to improve the station surroundings, and on whether local development may occur as a result of a station. For example, parking lots large enough to permit riders to "park and ride" may be required before owners will agree to an intermediate stop. By the same token, if the system draws many riders, local governments and private entrepreneurs may wish to develop the area around the station.

[9]Rail Passenger Service Act of 1970.

[10]John D. Heffner, "The Legal Obstacles for Initiating Intercity Rail Passenger Service Outside Amtrak," paper, Apr. 28, 1983.

*Class 4 track limits passenger and freight train speeds to 80 and 60 mph respectively.

[11]Information provided by Gordon Peters, New York State Department of Transportation.

In most instances in which high-speed rail may be contemplated, local transit is assumed necessary to feed riders into the intercity service, as illustrated in many European and Japanese cities. Proponents of the high-speed rail system in question may locate stations to maximize ridership for both systems. If local transit systems are inadequate, the potential of high-speed rail proposals may be reduced. Or, if demand for the high-speed intercity service is strong enough, there could be pressures on the city and the Federal Government to strengthen the local transit systems.

SOURCES OF FUNDING

Reaction to high-speed rail proposals also will depend on the sources of funding. Broadly speaking, there are four funding possibilities:

- Federal support,
- State support,
- private support, and
- a combination of private and public support (State or Federal).

Federal Support

Potential use of Federal money may range from direct subsidy to land grants or loan guarantees. Federal support of any kind raises a number of issues. Is the proposed system cost effective? If not, does use of Federal funds for high-speed rail fit into national priorities? Are there alternative options for service that will cost the public less? If Federal support is used for high-speed rail, how will that affect the financial situation of other modes and Amtrak?

Another issue likely to arise is the fairness of using Federal money to establish high-speed rail service in one or two locations or corridors and not on a broad national basis. Whether a consensus can be reached on such an issue probably will depend on how much Federal money is involved, and whether only an initial expense or a sustained subsidy is required. Also relevant is the willingness of a region in which the rail service is being contemplated to invest its own resources to ensure success, and the political support from the given region.

Federal money also could precipitate opposition by groups that stand to lose from the use of high-speed rail. Among these are proponents of traditional train service and competitors of high-speed rail. Not all rail advocates are proponents of high-speed rail. Some feel that the establishment of high-speed rail could lead to the decline of Amtrak and existing long-distance rail service. There is also a belief that if Federal investment were to occur, the logical next step is upgrading existing service. If Federal money is used, however, some worry that Amtrak's budget for existing service will be cut in proportion to Federal money spent on high-speed service or that, at the least, attention will be diverted from the broader question of national rail service.

Opposition to the use of Federal funds for high-speed rail is also likely to come from bus companies and airlines offering competing service. The bus companies have testified repeatedly in Amtrak hearings that they regard the subsidization of train service with Federal money to be anti-competitive and unfair. The airlines may feel likewise. On the other hand, Amtrak previously has argued that other transportation modes are subsidized, through infrastructure programs and the like. As previously indicated, recent Congressional Budget Office analysis show passenger rail receives greater subsidies than other intercity travel modes.

In short, the use of Federal money for high-speed rail raises three questions: 1) is the money being spent to best ensure an efficient national transportation system, 2) who should benefit from a corridor development if it is to be federally funded, and 3) is it in the long-term interests of the country to develop a high-speed rail irrespective of the short-term costs and possible subsidy?

State Support

Use of State money raises issues similar to that of Federal money but on a State level. If the proposition is not expected to pay for itself, one can certainly expect outcry from others competing for State funds.

Private Money

Use of private money presupposes that the high-speed rail venture is expected to be self-sufficient and operated for the benefit of investors in the project. If money for such a venture is to be raised in the private capital markets, the borrowing company will have to be a creditworthy. Even if the equity is financed by venture capitalists, there typically will be substantial amounts of debt which would be raised publicly or in private placements. In either situation, the creditworthiness of the company will be evaluated. Underwriters will have to certify that the prospectus is not unrealistic or misleading.

However a new venture is financed, any private group interested in providing high-speed rail service along routes Amtrak now operates must obtain a license from Amtrak. Amtrak has indicated that it is willing to grant a license only if the private group is willing to reimburse Amtrak for reduced passenger revenues attributable to competition from the new high-speed rail system.[12] Amtrak currently loses money on most of its routes. Its short-term avoidable costs are likely to increase with further loss of riders (unless service levels are decreased substantially or the route is dropped from Amtrak's route system).

[12] OTA interview with W. Graham Claytor, Jr., President of Amtrack, Feb. 10, 1983.

Chapter 5

U.S. PASSENGER RAIL HISTORY AND CURRENT CORRIDOR ACTIVITY

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Chapter 5

U.S. PASSENGER RAIL HISTORY AND CURRENT CORRIDOR ACTIVITY

SUMMARY

Interest in high-speed corridor development is emerging at both the local and national level. Feasibility studies of varying detail have been undertaken for corridors in California, Nevada, Wisconsin, Ohio, Illinois, Florida, and New York, and other studies are being discussed and initiated for Texas and Pennsylvania. Many of these studies have been conducted and funded by potential technology suppliers and developers, both foreign and U.S. —some with Federal and State assistance. Various technology options—including the Japanese bullet train (Shinkansen), the French TGV (Train a Grand Vitesse), the British HST (high-speed train), the West German and Japanese maglev (currently under development) —have been discussed in these studies.

Reasons for new corridor development are as diverse as the regions in which they are being proposed. For southern California, one of the most rapidly growing areas in the country, the system is seen as a means of alleviating the already staggering traffic congestion and the long-term demands for a fixed guideway transit infrastructure. For the Las Vegas-Los Angeles corridor, maglev is being proposed as the transportation system of tomorrow, a draw for tourists who might wish to take a new "transportation experience," and a potential spur to the development of Las Vegas. For Florida, a system is seen as a backup for any future energy crises that may threaten the State's tourist economy, and, as in Nevada, as a tourist attraction. In the Midwest, a new rail system has been advocated as a potential remedy to the economic problems of a region in transition.

Private initiatives to implement high-speed rail are in different planning stages in California, Florida, Michigan, New York, Vermont, Wisconsin, Ohio, Texas, Pennsylvania, and Nevada. In addition, a Midwest High-Speed Rail Compact made up of States interested in high-speed rail development also has been formed. These corridor efforts are being promoted, in part, by potential U.S. and foreign developers, suppliers of the technology, State and local government officials, and private companies interested in passenger rail service (see fig. 8).

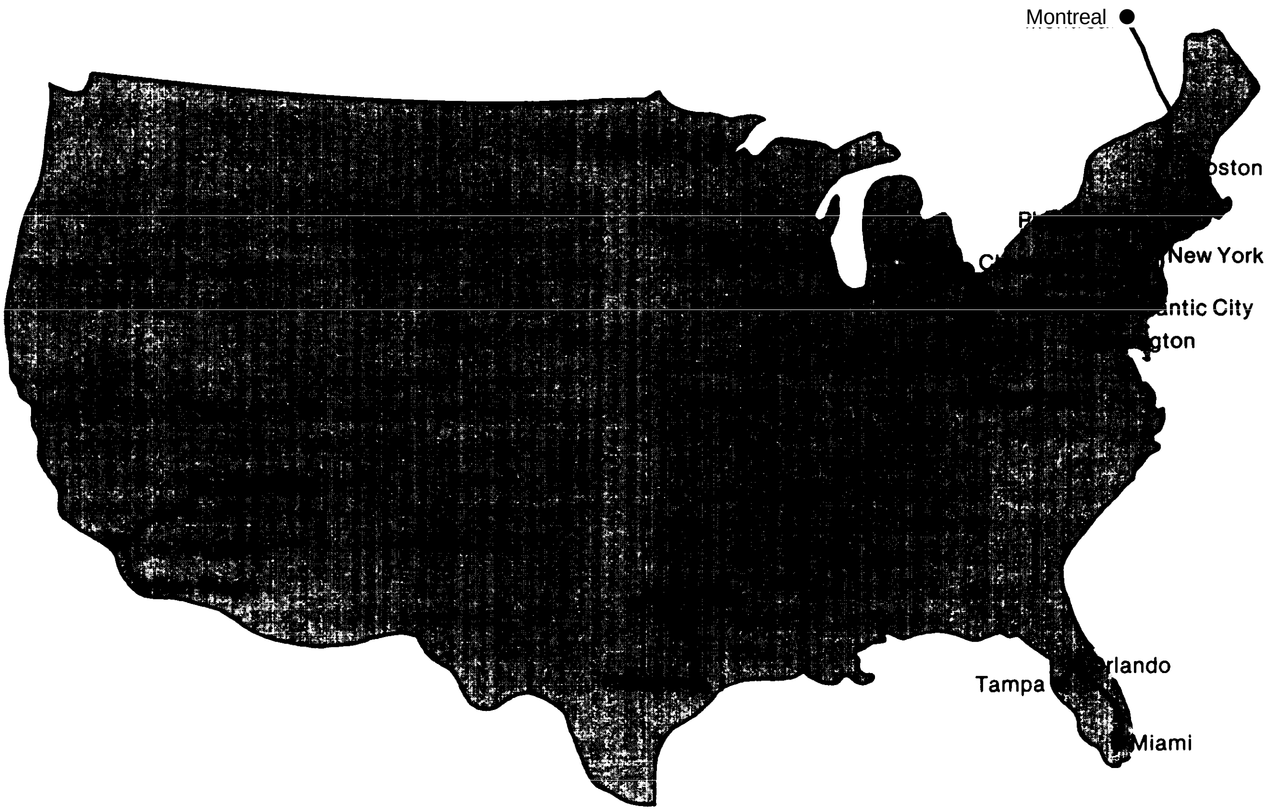
Among the reasons for high-speed rail service advanced by various States and private parties are improving transport capacity, relieving highway congestion, attracting tourists, spurring economic development, and serving as a backup form of transportation in the event of future energy crises.

The American High Speed Rail Corp. (AHSR), a private corporation, plans to construct a high-speed rail system between Los Angeles and San Diego. Ridership and revenue forecasts on the project have been conducted and engineering feasibility work is being undertaken by the Japanese.

In the proposed New York and Florida corridors, preliminary technical feasibility studies are being conducted by French, Canadian, and Japaese firms. However, results of these studies are not available to the public. Demand and economic analyses have not yet been conducted.

In Nevada and Wisconsin, studies conducted by potential suppliers of maglev technology have concluded that maglev is an appropriate, cost effective new transportation technology for the Las Vegas-Los Angeles and Milwaukee-Chicago corridors. The city of Las Vegas is actively seeking venture capital for the proposed Las Vegas to Los Angeles line and an additional feasibility study is being undertaken by the Department of Transportation as a result of recent congressional action. However, neither of the two maglev technologies currently under development in West Germany and Japan has been tested yet for operational feasibility under conditions that reflect revenue service. The West German system is undergoing testing that is scheduled for completion in late 1985.

Figure 8.—Raii Corridors Under Consideration by State and Locai Governments and Private Sector Groups



SOURCE: Off Ice of Technology Assessment.

The Michigan Department of Transportation has undertaken a series of studies on several Michigan corridors, examining alternatives that include upgrading existing lines and service and introducing frequent high-speed trains. These studies concluded that development of such services could reduce travel times, costs, and energy consumption in southern Michigan (particularly for a Chicago to Detroit line). The State sees the introduction of high-speed rail service as offering improved mobility and economic opportunities.

A proposed high-speed system in Ohio was to be financed by a one percent State sales tax. A referendum on the sales tax was defeated in 1982, although proponents believe the system is still a possibility for the State.

Other States, including Pennsylvania and Texas, have indicated an interest in high-speed rail corridors. Pennsylvania has established a Rail Commission to study the prospects. Texas has held statewide hearings. However, Texas has not conducted engineering or economic feasibility studies. Pennsylvania is undertaking initial study efforts.

In addition to high-speed initiatives, a number of corridors are being examined for upgrading service, although not necessarily to speeds of 125 mph and above. Atlantic City-Philadelphia and Buffalo-Albany are among these corridors. A corridor "fact sheet" describing each corridor is shown in table 11.

Table 11 .—Corridor Fact Sheet

Corridor	Proposer	Technology option	Estimated capital cost	Proposed funding institutional arrangement	Studied by
Los Angeles-San Diego	American High Speed Rail Corp. (AHSR)	130-mile system, new equipment, entirely new track, partly on existing right-of-way, Japanese technology	$3 billion (1983 $) inflated over construction time of 1984-88	Private/foreign investment-private rail operation. Private investment: 75% domestic, 25% foreign, Industrial development bonds/tax free authorized by State	Fluor Corp. Proj. Engineers, Japanese National Railways _Technology Corp. (engineering study), A. D. Little (market feasibility), First Boston Corp. (financial advisors)
Los Angeles-Las Vegas	City of Las Vegas	230-mile, totally new single guideway maglev system (West German or Japanese)	$1.9 billion (1982 $)	Tax-free bonds, private funding, public incentives (guaranteed loans, etc.) Public/private ownership	Budd Co. /Thyssen Henschel; Bechtel Corp.; Transrapid International; Transtech International
Florida corridor(s): Tampa-Orlando-Miami	AHSR, State Rail Committee appointed by Governor	Undecided	Unknown	Anticipated private funding	Japanese National Railways Technology Corp. (preliminary engineering), AHSR
Montreal-New York	Mayor of Montreal with New York cooperation	French TGV-type system	Unknown	Unknown	French manufacturers–preliminary engineering study/Canadians
Northeast Corridor: Washington-New York; New York-Boston		Completion of upgrading anticipated for 1986 Federal investment $2.19 billion		Route-shared/commuter, freight passenger service. Maximum speed: 120 mph along selected sections of the route	
Ohio	Ohio Rail Transportation Authority	500-mile network, TGV-type system, technology not chosen	$5.7 B (1978 $) +2.5 B $8.2 B	1 % State sales tax was defeated in 1982 referendum–no subsequent action on proposal	Dalton, Dalton, Newport
Pennsylvania	State legislature authorized 3-year Rail Study Commission	350-mile route Philadelphia-Pittsburg	Unknown	Unknown	Rail Committee authorized to spend up to $6 million on study over 3-year period
Chicago-Milwaukee	Cong. Henry S. Reuss; Gov. Dreyfus; Milwaukee County Executive William O'Donnell; Wisconsin Electric Power Co	79-mile system between Chicago-Milwaukee and two airports, Maglev system	$1.2 billion	Unknown	Budd Co. /Thyssen Henschel
Chicago-Detroit	Michigan State DOT	279 miles upgrading existing line/ possible new system	$2.5 million per route mile	Public/private	Transmark Worldwide Co.; General Motors System Center; Michigan State University

[a]Additional announcements have been made regarding Interest in a possible Texas corridor

SOURCE Office of Technology Assessment

RECENT HISTORY

The 1960's witnessed two major trends in U.S. passenger rail transportation:

- the promotion of advanced ground transport research and development (R&D), reflected in the passage of the High-Speed Ground Transportation Act of 1965 (HSGTA), which for a decade was intended to spur technology development in the public sector; and
- the transfer of the declining passenger rail industry from the private to public domain, culminating in 1970 with the passage of the National Railroad Passenger Act (NRPA).

The Northeast Corridor Transportation Project, started in 1963, foreshadowed HSGTA and eventually attempted to use some HSGTA developments to reverse declining rail ridership trends, and to show the continued value of rail in the most heavily populated U.S. corridor.

HSGTA came at a time when the U.S. space program had created an atmosphere of technological optimism and a national desire to apply scientific knowledge and expertise to domestic problems. The act resulted in a decade of research, development, and demonstration programs in state-of-the-art and advanced fixed guideway ground transportation technologies. Efforts included a wide range of research in new technologies such as tracked air cushion vehicles and magnetic levitation (maglev), demonstration of the Metroliner cars and turbotrains on the Northeast Corridor (NEC), and NEC ridership data-gathering efforts. At about the same time, Congress authorized a comprehensive study of improved trains in the NEC. Continued funding of the act into the 1970's led to the construction and development of the Pueblo test site in Colorado for advanced ground transport testing.

Various rail technology options were studied for the NEC in the late 1960's and early 1970's. By 1971, a report was released by the U.S. Department of Transportation (DOT) recommending improved high-speed rail service for the NEC and calling for a definite investment plan by 1976. Later cost overruns and project reevaluation resulted in improved service to a maximum speed of *120* mph on sections of the NEC, rather than to higher speeds that had been anticipated. Also, in 1973, DOT released a High Speed Ground Transportation Alternatives Study which reviewed additional interurban corridors in the context of potential economic viability and technology applicability. The report recommended continued R&D, and cautioned against any corridor implementation without thorough cost analyses.[1] However, the Southwest Coast Corridor (SWC) of San Diego-Los Angeles ranked second to the NEC in potential for improved rail service.

The second change that occurred in the *1960's* and culminated in *1970* was the evolution of passenger rail service from private operation to public ownership. The decline in intercity rail ridership in the 1950's—brought on by the introduction of the interstate highway system, the national airport system, increasing auto ownership, and a decline of local transit services, meant growing deficits in passenger rail services. As a result, railroads petitioned throughout the 196o's to abandon passenger service. In 1970, Congress enacted the NRPA creating the National Railroad Passenger Corp. (Amtrak) as the quasi-public operator for intercity rail passenger services in this country.

In the mid-1970's, Federal attention in passenger rail transportation concentrated on establishing and monitoring the rehabilitation of the NEC and overseeing the newly created Amtrak. National passenger rail policy in the years since has sought to reconcile the conflicting objectives of reducing operating deficits and at the same time providing national rail transportation services. The original Amtrak charter called for a profitmaking basis of operation. Congress currently requires Amtrak to maintain a national route system, to follow a prescribed formula for determining route profitability, and to meet a mandatory revenue-to-cost ratio of better than *50* percent for the railroad by the mid-1980's. Amtrak's goal is to cover all short-term avoidable costs with revenues by 1985.

[1] U.S. Department of Transportation, "High Speed Ground Transportation Alternatives Study," January 1973, pp. 1-10.

In 1980-81, Amtrak and DOT, in response to section 1003 of the Rail Passenger Service Act, undertook a study of 25 passenger rail corridors to determine the effects of corridor upgrading on deficit reductions. Corridors were evaluated on the basis of ridership potential, energy savings, and cost effectiveness—with cost effectiveness measured as dollars of public expenditure per passenger-mile and per gallon of gasoline saved, for both capital and operating investments.[2] Amtrak did not agree that both capital and operating costs should be used to measure cost effectiveness. However, DOT officials maintained that the language of the legislation required such measurements. Although the study did not analyze high-speed (125 mph rail or higher), it did analyze the potential for upgrading service to 79 and 110 mph and increasing service frequency. The study provided a rank ordering of the corridors likely to lose the least money with higher speeds and frequency. None of the corridors analyzed were expected to show operating profits once the service was improved, nor were they expected to pay back the costs of improvements. However, several corridors showed an improved financial operating picture. Again, the Los Angeles-San Diego corridor compared favorably with the Washington-New York segment of the NEC on the basis of avoidable loss per passenger-mile and a public expenditure per passenger-mile.

Today, U.S. intercity passenger rail accounts for less than 1 percent of intercity revenue miles. Amtrak operates approximately 240 daily trains over 24,000 miles of track (most of which is owned by the freight railroads) with approximately 1,600 vehicles serving 525 stations. Annual ridership has grown from 15,800,000 in 1972 to 19 million in 1982, with ridership surges during the energy crisis years of 1974, 1979, and 1980.[3] Federal subsidy to Amtrak was $735 million in 1982.

[2]U. S. Department of Transportation and Amtrak, "Rail Passenger Corridors, Final Evaluation," April 1981.

[3]Responses to OTA questions from W. Graham Claytor, Jr., President, National Rail Passenger Corp. (Amtrak), Feb. 10, 1983.

U.S. HIGH-SPEED RAIL PROPOSALS

Following are brief descriptions of the activities to date on each of the U.S. corridors for which fixed-guideway systems operating at speeds of 125 mph or above are being contemplated. This section discusses the feasibility data (ridership and revenue forecasts) generated to date, and raises additional questions that may be addressed by the communities and their leaders—local, State, and Federal—who may decide further courses of action.

The descriptions are not exhaustive. OTA has not undertaken independent analyses of ridership and revenue forecasts. The purpose of the section that follows is to review the current state of these projects and to raise some of the questions that bear on their feasibility. *

● Information contained in the following sections was obtained in the first seven months of 1983. While specific Rail Plans are subject to change, the questions raised for each corridor are fundamental to the policy discussion.

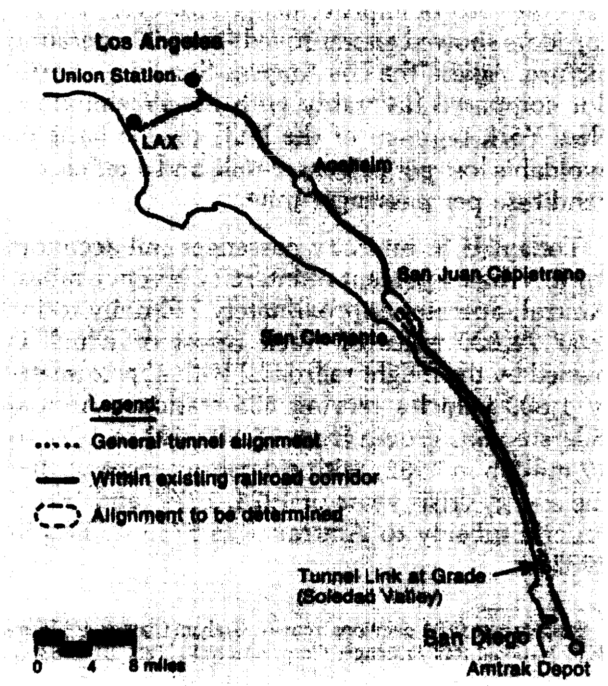
California: Los Angeles to San Diego (SWC)

One of the most serious proposals for high-speed rail in the United States has been made by AHSR for the 131-mile SWC with a segment linking Los Angeles airport to downtown (see fig. 9). Next to the NEC, the SWC historically has been regarded as the most likely candidate for possible passenger rail improvements.' The SWC also has been the subject of a number of studies by the California State Department of Transportation.

In April 1982, AHSR, a private corporation headed by Alan Boyd, then President of Amtrak,

'U.S. Department of Transportation, "High Speed Ground Transportation Alternatives Study," January 1973, pp. 1-10; U.S. Department of Transportation and Amtrak, "Rail Passenger Corridors, Final Evaluation," April 1981.

Figure 9.—Los Angeles-San Diego Proposed Route



SOURCE: American High Speed Rail Corp.

announced plans to construct a high-speed rail system between Los Angeles and San Diego. The First Boston Corp. was retained as the company's financial investment advisor. The Fluor Corp. has been retained as project engineer. AHSR's ridership and revenue forecast studies have been conducted by Arthur D. Little Co., and its engineering feasibility work is being undertaken by the Japanese National Railroad Technology Corp., a consulting arm of the Japanese National Railways. AHSR has deemed the complete ridership and revenue forecasts as proprietary for investment financing reasons and has declined to make these or the engineering cost analyses available to the public or OTA. Information used in this discussion has been extracted from summary documents and interviews with AHSR officials.

Initially, AHSR estimated that the overall capital cost of the system would be $2 billion. More recent estimates add $1.1 billion for inflation provisions, plus interest during construction, for a total cost of approximately $3.1 billion. The planned 5-year construction phase is scheduled to begin in 1984 with completion by 1989. Operating expenses for the first full year of operation (1989) are estimated at $200 million and revenues at $575 million. The Bank of Tokyo Trust Co. has agreed to raise 25 percent of the original $2 billion in capital. The remaining is to be raised in the private investment market.

In the summer of 1982, the California Legislature passed a law allowing potential rail companies to apply for up to $1.25 billion in tax-free bonds and exempting certain actions such as the granting of rights-of-way from environmental review by the State Public Utilities Commission. Review and approval must be obtained by the State Treasurer and State Rail Passenger Financing Commission, established for the purpose of issuing the bonds. AHSR officials indicated that a complete environmental review in compliance with both Federal and State environmental protection standards will be undertaken.

AHSR's original plan called for using the Interstate Highway right-of-way to construct, for $2 billion, *new* grade-separated tracks over which it hoped to run modified Japanese bullet train sets of eight cars each at average speeds of 125 mph and top speeds of 160 mph. Nonstop travel time from Los Angeles to San Diego was estimated at 59 minutes, with a 15- to 20-minute run scheduled from downtown Los Angeles to the airports More recently, AHSR indicated that it intends to build new track along the existing railroad rights-of-way, sections of which are owned by the Atchison, Topeka, and Sante Fe Railroad, and by the Southern Pacific Railroad. A significant portion of new right-of-way still would be required, since plans call for saving time by cutting through the mountains into San Diego and for better access into Los Angeles. A small portion of Interstate 5 right-of-way is also needed.

The AHSR proposal calls for 16 miles (12 percent) of tunnel, 50 miles (38 percent) of elevated grade-separated viaduct guideway, and 65.5 miles (50 percent) cut-and-fill grade. According to AHSR, the greatest proportion of tunneling will use direct bore techniques.

[1]Information regarding AHSR plans was drawn from the summary reports on "Engineering and Construction" and "Market Study," published by American High Speed Rail Corp., March 1983, as well as by conversation with AHSP staff.

AHSR reportedly expects to carry, on 86 trains, 100,000 persons daily (36.5 million passengers annually) with trains running at 30- and 10-minute frequencies. The ridership projections represent over 12 percent of the total automobile, rail, air, and bus trips made daily in the region, according to AHSR data, with more than 20 million trips diverted from the automobile. By contrast, Amtrak currently carries 3,000 passengers daily (about 1 million passengers annually) on seven round trips between Los Angeles and San Diego. [b] Current Amtrak service provides for departures every other hour.

AHSR assumes that by 1988 traffic on Interstate 5 will become so congested that highway travel time between San Diego and Los Angeles will increase to 3½ hours from the present 2½hours. AHSR ridership estimates also were calculated on the basis of total trips generated in areas within a 5- to 10-mile radius of the station locations, assuming six or seven stations. *

Current demographic characteristics of the SWC indicate a population of approximately 10 million people, with 1990 projections at 12.6 million. Using AHSR ridership figures of 36.5 million passengers annually, the data indicates that on the average every person would take at least 3.7 rail trips annually.

A number of unanswered questions remain about the current proposal: Would local travelers use high-speed rail? At what fare? Does AHSR intend the high-speed rail line as a commuter transit system as well as an intercity system? If so, how do these plans mesh with current city of Los Angeles plans for a transit system? Are the projected construction costs reasonable given the anticipated tunneling and viaducts required? Is there a sufficient local transit infrastructure to feed the high-speed rail link? Will the highways become so congested that people will divert to rail, or are there alternatives available that may be less costly than a completely new rail system? What effects will a high-speed service have on the air and bus market? What will happen to Amtrak's service if AHSR plans to use existing rights-of-way to construct its bullet train route? Legally, Amtrak maintains sole licensing responsibility for passenger rail service in the United States. In an interview with OTA, Amtrak President W. Graham Claytor, Jr., indicated that Amtrak has negotiated an agreement so that AHSR can provide high-speed rail in the same corridor as long as it is reimbursed for its lost revenues and receives a percentage of the profits.

California and Nevada: Las Vegas to Los Angeles

The mayor of Las Vegas has proposed a superspeed (250 mph) maglev ground transportation system between Los Angeles and Las Vegas. On January 27, 1983, the city of Las Vegas, in conjunction with the Clark County Board of Commissioners, the Las Vegas Convention and Visitors Authority, and the State of Nevada, released a feasibility study of the system. The study was prepared by the Budd Co., a potential supplier of maglev equipment—assisted by Bechtel Corp., Transrapid International, * and Transtech International, Inc. ** The study recommends construction of a 230-mile route from the Ontario airport outside Los Angeles, through the Cajon Pass, and into Union Plaza in Las Vegas. The route parallels Interstate 15 much of the way and would require little land acquisition since most of the proposed right-of-way is on Federal or State-owned property, assuming such property is made available.

The study recommends that the system be implemented by a joint public-private enterprise, in order to "permit utilization of available Federal tax incentives, encourage funding from a variety of sources, and result in a broader ownership base."[7] However, it also indicates that the system

[6]Responses to OTA questions from Amtrak, February 1983.

* Some OTA workshop participants believe that, for intercity travel, the base travel level used by AHSR to determine projected ridership may have been too large, because local trips were calculated in AHSR assumptions. Participants suggested that fare costs and overall trip time constraints for local trips may preclude people from using the 160 mph system to travel locally or for commuting. If local trips are included, as AHSR brochures suggest, then larger theoretical amounts of travel result.

*Transrapid International is an association of firms including Messerschmidt-Boelkow-Blohm (MBB), Krauss Maffei, and Thyssen Henschel, who are responsible for the development of the maglev system in the Federal Republic of West Germany. Thyssen Henschel owns the Budd Co., located in the United States.

**A $150,000 DOT grant was also used in the initial feasibility effort.

[7]*Executive Summary, Las Vegas to Los Angeles High Speed/Super Speed Transportation System Feasibility Study, 1983,* p. 25.

can be built by the private sector. According to the study, a 20-percent return on equity would be possible if the system could attract 2.6 million passengers annually at a projected round trip fare of $65 (1980 values). Today, nearly 12 million people visit Las Vegas each year. Residents of the Los Angeles area account for approximately 3.6 million visitors, or about 30 percent of the total, most of whom travel to Las Vegas by car. The study projects that between 1.9 million to 2.7 million people, or over half of the ridership, could be induced to try the new mode.[8] The proposal calls for the line to originate near the Ontario airport, which is approximately a 45-minute drive for patrons living in Los Angeles and the surrounding coastal communities.

Even with these ridership projections, the study states that "this is probably not a high enough return to attract equity investors in view of the perceived risks associated with the project and the fact that positive returns to equity investors are several years into the future."[9] Financial analysis reveals that, for private ownership, operating income would be negative from 1983-96. Return on equity investment varies considerably from year to year and changes from negative to positive to negative, respectively, until 1999, when an increasing return is realized each year.

The results are similar for public ownership, although the years are slightly different due to an assumption that interest rates on capital costs would be 10 percent rather than 13 percent as in the case of private ownership. In public ownership, positive cash flow would occur 2 years after startup of operations (1992) and increase substantially thereafter.

In both cases, ridership would grow more slowly than net income and cash flow, because as the study assumes, fares would increase by 7 percent annually while debt costs would remain fixed. At the same time, operating costs are estimated to be very low. Excluding interest, operating costs are projected to be $55.2 million in 1991, while revenues from fares and food concessions are projected to be $395.2 million—a ratio of 14 percent. By 1991, the study also assumes the 1980 ridership will have increased to 3.1 million.

[8]Ibid.
[9]Ibid.

The total cost of the project is estimated to be $1.8 billion. Construction (guideway) and electrification costs are estimated $1.2 billion ($5.12 million per mile). Single-track operation is planned, limiting construction costs. Until cost verification and operational feasibility testing have been completed for the West German and Japanese systems, questions regarding maglev operating and capital costs for this, or any corridor, cannot be answered fully.

Florida: Tampa to Orlando to Miami

Florida has been interested in high-speed rail since the energy crisis of 1973-74 cut into the State's tourism revenues. Florida's flat terrain, low population densities between major coastal cities, and high tourism provide some advantages for high-speed rail systems. In addition, the population is one of the fastest growing in the country. Florida expects to attract *35* million to **40** million tourists in 1983.[10] However, while Florida's population and tourist levels indicate some potential for generating rail ridership at levels that may cover operating costs, most visitors to Florida now come by automobile, and many travel as part of a group (family or otherwise). Modal splits are currently estimated as 86 percent by automobile, 11 percent by air, 3 percent by bus and rail.

In April 1982, Florida established a High-Speed Rail Committee to investigate the potential application for the technology in the State. About the same time, AHSR announced its interest in a Tampa-Orlando-Miami corridor. The Japanese National Railways Technology Corp. and AHSR are conducting preliminary engineering and marketing studies of that corridor. Initial State efforts are concentrated on examining the feasibility of establishing a 255-mile high-speed rail route between Tampa and Miami via Orlando. No technology has been chosen yet for the route, though the State believes it must be a proven technology in order to attract investment.

The State Department of Transportation has provided topographic data for Japanese engineers, conducting the preliminary engineering study of the area, and the State DOT has also examined the feasibility of using median strips of the Florida

[10]Information provided by Florida Department of Transportation.

Turnpike for a high-speed rail corridor. However, highway curvature may limit the amount of right-of-way that could be used for this purpose, although the State assumes public-owned rights-of-way will be made available. To date, Florida has not conducted a study to estimate ridership or determine economic feasibility.

A number of questions exist concerning this corridor: Are sufficient transit infrastructures available (or planned) to feed the rail system? Would tourists, many of whom now come in by car from out of State, switch modes once in Florida? Could other tourists be induced to ride the train with the current cost, service, and convenience factors provided by competing modes? Would private capital be sufficient to cover a project of that magnitude? Are there transportation alternatives that might better meet the State's needs?

Michigan: Chicago to Detroit

The Michigan Department of Transportation (MDOT) has conducted several studies of corridors within the State, analyzing options for upgrading and for introducing high-speed rail service. MDOT considers the Chicago-Detroit corridor to offer the most significant potential. The improved service offered by the proposed route, and the potential for improved economic and employment opportunities, are seen as the chief reasons for the new or improved rail service.

The Chicago-Detroit corridor has a number of the features necessary for a high-speed rail route, including a route distance of 279 miles, and a corridor population of 12,5 million people. State rail officials view the corridor as having travel affinity between the two cities, especially for business and for the connecting links to Canada's most populated corridor. Amtrak currently operates daily trains between Chicago and Detroit.

Feasibility studies of the corridor have been conducted by Transportation Systems and Market Research Ltd. (TRANSMARK), a British consulting firm. Ridership of 4.6 million to 6 million intercity passengers annually for the year 2000 was projected for the corridor with intermediate feeder routes extending to Lansing and Grand Rapids. It is expected that most of the travel will be diversion from other modes (77 percent), with only 15 percent of new induced demand. Service assumed 125-mph speeds. The analysis examined the option for upgrading service, using available technology, to achieve the 125-mph speeds. Additional work is being conducted to determine rights-of-way that may permit speeds up to 160 mph. The upgrading options suggest a cost of $2.5 million per mile is necessary to achieve the 125-mph speeds.[11]

The MDOT studies suggest that revenue from the Chicago-Detroit corridor may not be sufficient to support total operating, maintenance, and investment costs and offer a return on investment. However, they believe nearly sufficient revenues will be generated to cover operating costs. MDOT believes some form of public sector incentive or stimulus is necessary to generate private sector participation. Key questions remain about the projected financing options that could be used for such a project.

Midwest High-Speed Rail Compact

In 1980, the State Legislatures of Michigan, Illinois, Indiana, Ohio, and Pennsylvania established the High-Speed Rail Compact to foster the potential economic development, employment, and transport benefits that might result in the Midwest from new rail service. The Compact called for the Governors of each State to appoint two representatives. The Compact meets twice a year to exchange information on new rail developments and to foster interest at State, regional, and Federal levels in high-speed rail projects.

New York: Montreal to New York City (State Rail Plans)

The State of New York has undertaken perhaps the most comprehensive passenger rail upgrading program of any State in the Union. In the late 1960's, the State DOT began looking at foreign passenger rail activity in France and Japan. In the early 1970's, the State undertook a conceptual

[11]Information provided by Michigan Department of Transportation.

study designed to analyze high-speed rail in several corridors. In 1974, $50 million of a $250 million State bond issue was devoted to upgrading passenger rail rights-of-way. Another bond issue for which additional moneys were allocated to rail was passed in 1979. Using a phased approach with rail bond funds (State initiated), this effort has brought over 94 miles of the New York City-Albany-Niagara Falls passenger corridor to speeds up to 110 mph. An additional 42 miles of route are due to be similarly posted for high speeds in the near future. According to State rail officials, the State's incremental approach to rail improvement is designed to build a ridership base while ascertaining the revenue increases that result from the capital improvements the State has made. The State has invested about $80 million in track improvements. One project currently under study for a high-speed rail system is the Montreal-New York City corridor. The projected corridor is a cooperative effort between the mayor of Montreal and the States of New York and Vermont. To date, a preliminary engineering feasibility study of an advanced French TGV-type system has been conducted, funded by Montreal. New York DOT provided technical assistance to the study. The study has not yet been released.

The next phase, which New York and Vermont are discussing with Canada, includes economic feasibility studies and patronage forecasts. Since the project would be a joint venture, both New York and Vermont have requested that Montreal obtain a formal commitment with the Province of Quebec supporting the project, since Quebec will be affected by the route. Approximately 40 miles of the route would be in Canada, while the remaining portions (330 miles) of the system would be in Vermont and New York.[12]

Northeast Corridor

Due to its population densities and transit systems, the corridor with the greatest potential market for high-speed rail is the NEC (Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, and the District of Columbia). Because of this potential, Congress enacted legislation to purchase the right-of-way in the corridor from Conrail* and to improve the roadbed to permit higher speed passenger train travel. The Northeast Corridor Improvement Project (NECIP) was authorized in 1976, and some construction began in 1977. Completion is scheduled for 1986, and funding authorized for the corridor totals $2.5 billion.

The NECIP investment will permit Amtrak passenger trains to reach speeds of 120 to 125 mph. Current best schedules permit maximum speed of 110 mph with an average 80 mph. Speeds up to 120 mph on selected sections of the corridor now have been approved. Twenty-six round trips daily are offered between New York City and Washington, D.C. In 1982, ridership for the corridor was 10.5 million people. The U.S. DOT estimates that approximately 80 percent of those passengers travel on the 224-mile sector between Washington and New York. Fastest trip time between New York City and Washington currently is 2 hours 49 minutes; upon completion of the project, best nonstop trip time is expected to be 2 hours 40 minutes. Additional incremental improvements to reduce trip times could be made with additional investment. At this time, however, there are no plans by the current administration for further investments beyond the $2.19 billion already allocated, until the current project is completed. According to DOT officials, the average cost per mile for NEC upgrading has been $4.5 million to $5 million with an additional $2.5 million per mile for electrification.[13]

Ohio

In 1980, the Ohio Rail Transportation Authority (ORTA) released the results of a high-speed rail study with the recommendation that a high-speed rail network be established to connect major cities of Ohio via three main corridors. The plan called for new grade-separated track and signals/communication facilities to permit operating speeds of 150 mph. The type of equipment to be operated on these tracks (TGV, bullet train, or APT) was left to further study, but costs were based on TGV equipment costs and capabilities. It was projected that it would take up to 15 years to acquire the land, complete construction, and begin operations.

[12]Information provided by the New York State Department of Transportation.

● Consolidated Rail Corp.

[13] Riego Mongini, Northeast Corridor Improvement Project, Intercity Programs Office, Federal Railroad Administration.

Capital costs of the basic 500-mile network were estimated to be $5.7 billion (1978 dollars) ($11.4 million per mile). The additional Toledo-Detroit and Youngstown-Pittsburgh segments were estimated to cost an additional $2.5 billion. In current dollars, the total cost for the basic network is $14.6 billion.[14]

Construction of the network was to be financed from a l-percent increase in the State sales tax. The tax referendum for the construction of such a system was defeated by Ohio voters in the November 1982 election by a 3:1 margin. Proponents argue that the defeat signaled opposition to the financing mechanism more than to the concept itself.

Impetus for the proposal was twofold: to provide energy-efficient intercity transportation (the system was to be electric-powered allowing use of Ohio coal as a source of energy) and to serve as a catalyst for economic revitalization.

Total ridership over the system was projected to reach 8.7 million passengers by the year 2000. Passenger trips would be spread out over 500 miles of rail network, with the average trip length (for the Ohio passengers) expected to be *109* miles.[15]

Ohio's rail service today consists of Amtrak's Lakeshore Ltd. & Broadway Ltd., and Cardinal trains running east-west through Ohio to Chicago. There is no north-south rail service, nor does Ohio now have any 403 (b)* rail service. Rail ridership is expected to be generated by diverting travelers from the automobile to the train as fuel prices increase and as population grows.

In the proposed Ohio network, where distances are short, as from Cleveland to Akron, rail would not be able to compete as successfully as other modes and is projected to get only 5 percent of the market. On the longest segment, from Cleveland to Cincinnati, the rail mode is projected to capture *58* percent of the market. The bulk of the traffic is projected to be diversion from the automobile. In 1977, approximately 74 percent of all traffic between these two cities moved by auto; by 2000, proponents of the network estimate automobile share of the market would have dropped to only 27 percent.

The network is projected to generate a profit; the operating ratio in 2000 is projected to be 69 percent. Operating income (before taxes) is expected to be $47.6 million which, if used for such a purpose, could support a debt load of only $470 million at 10-percent interest rates. The projected profits from the railroad do not appear to equal the construction costs of the network. For this reason, an increase in the State sales tax of 1 percent was proposed as a financing mechanism.

On a unit basis, operating costs are estimated to be 11 cents per passenger-mile. This compares with current air costs in the range of 10 to 15 cents per passenger-mile for travel in short (200-mile) corridors.

Although not defined as high-speed rail, the Ohio Association of Railroad Passengers recently has proposed the establishment of a 110-mph service on a 1,650-mile network within the State. The Association claims this would cost *$2.4* billion in contrast to the ORTA proposal of $11.5 billion for 526 route-miles.[16]

Pennsylvania

The Pennsylvania Legislature formed a High-Speed Rail Commission in 1982 to study high-speed passenger rail feasibility in the State. Prior to legislative approval of the Commission, the Milrite (Make Industry and Labor Right in Today's Economy) Commission, a group of business, labor, and political leaders convened to investigate the subject. On the basis of their findings, the Legislature approved a $6 million authorization for the State's High-Speed Rail Commission. The original Milrite study looked at a 351-mile route between Philadelphia and Pittsburgh. The High-Speed Rail Commission is authorized for 5

[14] Information on the Ohio plan was obtained from Ohio Rail Transportation Authority documents on the "Ohio High Speed Intercity Rail Passenger Program," published July 1980, with Dalton, Dalton & Newport as project consultants.

[15] Ibid.

* 403 (b) service is a State-Federal matching program for provision of passenger rail services. The States provide 45 percent of the operating funds and 50 percent of capital costs in the first year of operation. After that, the State provides 65 percent of the operating costs annually and the Federal Government provides 35 percent.

[16] Information provided by the National Railroad passenger Association.

years. A request for proposals to study the corridor has been issued. A 2-year study effort is being conducted.[17]

Wisconsin: Chicago to Milwaukee

An 80-mile maglev system has been proposed between Chicago and Milwaukee, at a cost of $1.2 billion ($15 million per mile). One goal of the route would be to divert air travelers from Chicago's O'Hare International Airport to Mitchell field, located outside Milwaukee, alleviating congestion at O'Hare.

Amtrak currently serves the Chicago-Milwaukee market with three daily trains round trip. Service was formerly six trains daily but was cut in 1981. Ridership in 1980 on the Amtrak between Chicago and Milwaukee was about 311,000 people, an increase of 100,000 over the decade. The operating deficit of the route was $6.2 million for the 1979-80 period. A feasibility study of the maglev proposal was undertaken by the Budd Co., a potential supplier of the maglev system. Annual operating costs for 24 daily round trips with seven 400-passenger trains are estimated at $13 million. At this cost, the Budd study concluded that such a system was "technically feasible, assuming the round-trip fare is $40.00, and an annual ridership of 2.5 million passengers is attracted."[18]

An actual ridership forecast, however, was not part of the feasibility study. The theoretical $2.5 million break-even ridership described in the Budd study represents 30 percent of the present Milwaukee-Chicago traffic. The projected fare of 25 cents per mile is substantially higher than the automobile costs.

In 1981, the Wisconsin DOT issued a study that concluded the large public investment in capital improvements to existing service, and the continuing operating subsidies necessary for new passenger train services in existing and new corridors could not be justified in the near future. Further, the study indicated that if Amtrak service were ever discontinued, alternatives including bus service to existing Amtrak service are available to provide adequate, comparable, cost-effective and energy-efficient service to the public. While this study did not examine high-speed or maglev applications in the proposed corridor, it did indicate that the Wisconsin DOT does not seek to implement any new rail corridors unless financial feasibility can be shown and public benefit justified.[19]

Texas

Texas State legislators and AHSR have indicated interest in a high-speed rail system for sections of the State. Recently, the Texas Railroad Transportation Co., formed in July 1983, announced plans for a high-speed rail system between Dallas and Houston using French equipment and bankrupt Rock Island Railroad rights-of-way. While general hearings have been conducted in the State, feasibility studies have not yet been undertaken by either the State or the interested corporations.

Other Corridor Plans

The Atlantic City-Philadelphia corridor has been the subject of several studies. Recent Federal legislation authorized $3o million to restore rail service on what was badly deteriorated track. While not anticipated as high-speed, the service is intended to provide relief on the congested routes between Atlantic City and Philadelphia by allowing for "chartered trains" and six round trips daily for commuters and others. In the DOT/Amtrak "Emerging Corridors" study—not a high-speed analysis—the Philadelphia-Atlantic City Corridor was reported to have a favorable performance for system upgrading in terms of ridership projections and the annual public expenditure cost per incremental passenger-mile.[20]

In addition to the New Jersey plans for upgrading service, significant improvements have been made on the New York-Albany-Buffalo corridor.

[17]Information provided by Robert Casey, Pennsylvania High-Speed Rail Commission.
[18]Information drawn from the "Final Report: Milwaukee to Chicago Maglev System Feasibility Study," by the Budd Technical Center, Dec. 10, 1982.
[19]Wisconsin Transportation Planning Program, "Rail Passenger Services Study," Wisconsin Department of Transportation, August 1981.
[20]"Rail Passenger Corridors: Final Evaluation," U.S. Department of Transportation and Amtrak, April 1981, p. vii.

Chapter 6

MAGNETIC LEVITATION: STATUS AND OUTLOOK

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Chapter 6
MAGNETIC LEVITATION: STATUS AND OUTLOOK

SUMMARY

Technology Status

Two different technologies using magnetic levitation (maglev) for high-speed intercity passenger service are being developed abroad. One, called attraction or electromagnetic suspension (EMS) maglev technology, employs conventional iron-core electromagnets, and is being developed by the Federal Republic of Germany. The other, called repulsion or electrodynamics suspension (EDS) maglev technology, employs superconducting magnets, and is being developed by Japan.

Both systems rely on electromagnetic forces to provide support (levitation), lateral guidance and propulsion (and braking) without direct physical contact between the vehicle and the guideway.

The attraction maglev system floats about ½ inch from the guideway surface and can levitate at any speed. The repulsion system floats about 4 inches away, but only works after sufficient forward velocity to achieve electrodynamics levitation is reached. Repulsion systems also require auxiliary wheels for support at low speeds.

The attraction system requires electronic sensing of the gap and continuous control of the magnetic current to achieve stable levitation. The repulsion system can levitate stably once sufficient forward velocity is attained.

Maglev systems are reported to have several advantageous features including:

- low track and vehicle repair and maintenance costs because of the low guideway loading and freedom from mechanical contact;
- higher speed capabilities with the resulting potential for improved productivity;
- enhanced safety, since derailment is theoretically impossible;
- less vibration and noise than conventional rail technologies; and
- low sensitivity to weather conditions due to elimination of mechanical contact between the guideway and the vehicle.

To date, neither technology has been tested and operated at sustained speeds or under the conditions required to demonstrate performance at levels and costs suitable for actual revenue service. However, the West German attraction maglev technology now has moved to the developmental testing stage. The West German tests are being conducted at the Emsland Test Facility in Lower Saxony. Complete test results are anticipated in late 1985 or early 1986. They will put one (two-car) system through approximately 160,000 miles of operation in the initial year of testing. * The Japanese repulsion maglev technology is still in the experimental stage, and, according to the Japanese National Railways (JNR), it will probably take 10 years before testing and demonstration are completed. '

Substantial technical development and testing still is required for both technologies, although there appear to be no insurmountable technical obstacles. A West German power distribution and conditioning system which controls the large amounts of power and the frequency required for propulsion is to be tested.[2] There are operational and cost uncertainties to be tested in this system. Additional development and funding may be required before it is ready for revenue service.

For the Japanese (repulsion) technology, development of a power conditioning system, and further research is required as well on the cryogenics

***According to Budd Co. officials, the initial year and 160,000 miles of tests will occur on the Emsland test track before the Southern loop of the facility is completed. Thereafter, they anticipate approximately 500,000 miles of tests annuall, as published in the Transrapid brochure.**

'Responses to OTA questions by JNR official, Ichiroh Mitsui, February 1983.

'The Budd Co.

(the cryostat and refrigerator necessary for the superconducting magnets).

Concerns about maglev technologies that remain to be addressed in demonstration and testing include:

- suitable, reliable, and stable guideway structures since the gaps are small (½ inch for the attraction and 4 inches for the repulsion system) between the guideway and the vehicle, and the ability of the maglev suspension to follow gap variation is limited;
- emergency procedures and the suitability of current service restoration schemes in the event of breakdowns;
- possible electromagnetic interference in the electrical systems near maglev corridors;
- for the repulsion system, the effects of the superconducting magnets' electromagnetic fields on the passengers;
- the reliability and maintenance costs for both wheel and levitation components to be used in the repulsion system and, for the levitation components in the attraction system. Also whether wheels (currently not included in the attraction system design) will be needed as a backup in case of system failure;
- the performance level of switching devices; and
- positive detection and safety in the event of guideway defects and obstacles.

Economic Feasibility

Capital and operating costs of maglev systems have been projected by technology developers. Those theoretical projections were not studied in this report. While some approximation of capital costs may be possible, the reliability of such projections must be examined in the context of the actual experience, testing and demonstration, particularly for guideways. Similarly, operating costs must be verified through tests and demonstrations under conditions that fully reflect revenue service. Given the fact that the systems have never been run at speeds and under conditions that reflect actual service, reliability of cost projections remains a concern.

Preliminary cost estimates have been included in several feasibility studies of maglev corridors in the United States by potential suppliers of the technologies. Experts and developers of the technologies claim operating cost as well as other advantages over conventional high-speed rail technologies.

Comparison With Other Modes

Maglev technologies are often termed "flying trains" because they are noncontacting and combine the high speeds of aircraft and the fixed guideway of trains. In a technical sense, maglev differs from conventional high-speed rail technology in many ways. In terms of the service it offers, however, the primary difference between maglev and conventional high-speed rail is speeds up to 50 to 150 mph higher than steel-wheel on rail technology.

Maglev proponents cite as an advantage the expected reduction in maintenance costs from having fewer moving parts with no friction from movement and pressure as in wheels on rails. Developers also claim reductions in land costs for the guideway if the structure is elevated, reductions in labor costs since the technology is highly automated, and reductions in noise and vibrational effect. Noise tests are scheduled at Emsland.

Economic comparisons between maglev and wheel-on-rail high-speed technologies are subject to question until more is known about the operating characteristics, and the operating and capital costs of maglev technologies. Aside from any cost differences, the "induced" demand that maglev might create because of its greater speed and novelty is a major factor making a maglev corridor appear more attractive to planners than other high-speed rail systems. Although there is no reliable way to predict how great "induced" demand might be, in one corridor proposal, estimates of "induced" demand represented approximately *50* percent of the total projected ridership.[3]

[3]Budd Co. Technical Center, "Executive Summary, Las Vegas to Los Angeles High Speed/Super Speed Ground Transportation System Feasibility Study," January 1983.

Two U.S. corridors have been considered for possible maglev introduction: Las Vegas-Los Angeles and Milwaukee-Chicago. Feasibility studies have been conducted on these corridors, by the developers or potential suppliers of the technologies. Las Vegas officials are actively seeking $10 million in venture capital for the project.

DISCUSSION

The search for an alternative to steel wheel on rail technology-with its high maintenance costs, noise, and energy consumption—is not new. Technologies explored include air and water cushion systems as well as magnetic levitation. However, attention increasingly has focused on maglev technologies as the most promising means to avoid many of the costs and problems associated with wheel-on-rail technology and, at the same time, to provide a smoother ride and much higher top speed than conventional rail could ever achieve. It became a serious contender as an alternative to the conventional airline in the 1960's, when it was believed that the capacity of airports in major cities soon would be exceeded and additional airports would be needed. New York considered a fourth airport, and London a third. Maglev seemed worth exploring as an alternative to the major expenditure, congestion, and environmental problems that additional airports would entail.[4]

Although the U.S. Government-sponsored maglev research programs from the National Science Foundation (NSF) and the Federal Rail Administration did not start until 1971, there were other U.S. programs supporting research and development of tracked air cushion vehicles and linear induction motors. U.S. maglev research and development was on a par with similar foreign research programs at the time the U.S. Government canceled it in the mid-1970's to shift to research in freight and conventional rail technology problems. The British, French, Canadian, and U.S. Governments, after study and some experimentation and have since abandoned work on high-speed maglev. The practical development of maglev technologies is now confined to West Germany and Japan.

'Comparative Assessment of New Forms of Intercity Transport, T. R. R. L., Report S. R.3., December 1971.

Maglev Systems

There are two basic kinds of magnetic suspension—attraction and repulsion—and both have been combined with a variety of linear motor configurations in the pasts

Attraction/Repulsion Suspension Technologies

Magnetic levitation can be achieved by attraction or repulsion technology. In the attraction system, the track is suspended from the guideway and the vehicle drawn magnetically upwards toward it. The vehicle has conventional iron-core electromagnets which are controlled to maintain a gap between track and vehicle. Similar devices maintain a gap between the side of the guideway and the vehicle. In the repulsion system, the aluminum track is below the vehicle and suspension is achieved by magnetic forces which push the vehicle away from the guideway. These forces result from vehicle speed and do not exist when the vehicle is at rest.

In the West German attraction system, the clearance between vehicle and guideway is about ½ inch and suspension is independent of speed.

In the Japanese repulsion system, the vehicles have a clearance of about 4 inches increasing with speed. At speeds below about 50 mph, the vehicle runs on wheels. Magnetic suspension occurs, and the vehicle "lifts off, " as higher speeds are reached.

Propulsion

Maglev vehicles use linear motors for noncontacting propulsion. The principle of linear motors

'Massachusetts Institute of Technology Library, "Long Term Assessment of Passenger Ground Transportation System Technology," 1982.

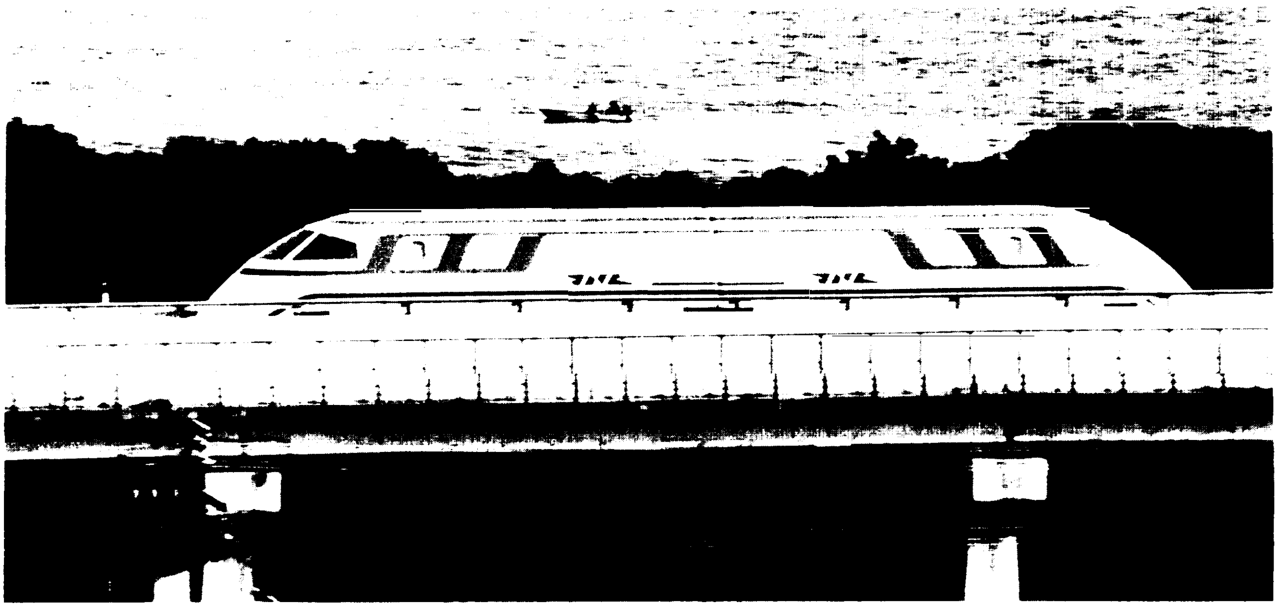


Photo credit: Japanese National Railways

Repulsion maglev MLV-001 test vehicle in Japan

is simple; they are analogous to common electric rotory motors, but with their components "unwound" as shown in figure 10. The primary (rotor) is the onboard component, and the secondary (stator) is the guideway bound component of the motor. Such motors also require a power-conditioning unit (PCU) to regulate the current (amount) and frequency of electrical power to develop the propulsion forces.

A variety of linear motor types have been developed and tested with maglev vehicles, but only the linear synchronous motor (LSM) is being developed currently for the high-speed application for either attraction and repulsion systems. LSMs locate the PCUs wayside primarily because of the size and weight of the PCUs and the problems of power supply to fast-moving vehicles.

To avoid powering the entire route (which would have unacceptable power losses), only the short sections of guideway on which vehicles are traveling are powered at a given time. This system provides automatically for safety separation of following tracks. These sections, called blocks, are typically 0.5 to 5 km long. The system for providing the sequential block activation is called the power distribution and conditioning system and includes the PCU.

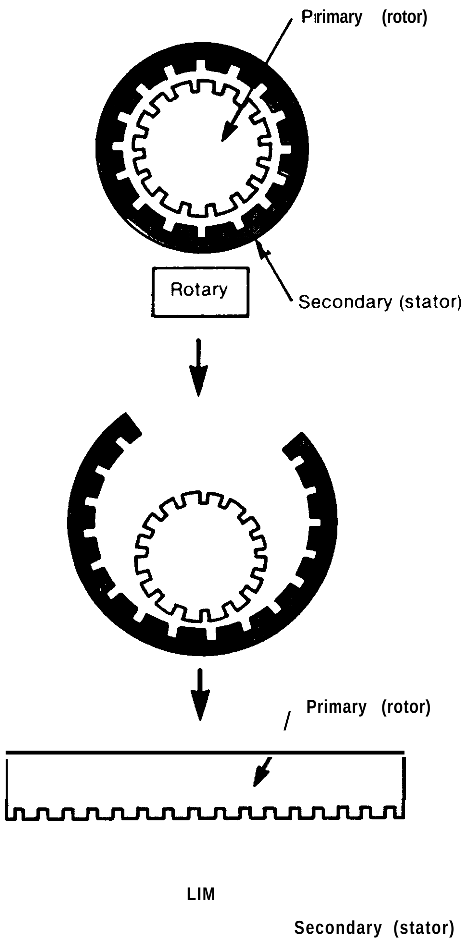
Power Distribution and Conditioning System

A major technical problem for both maglev systems is developing a power distribution and conditioning system suitable for revenue service. This system must control the large amounts of power required for propulsion of the vehicle. Two key aspects of this system are: 1) the power controlled by an individual PCU, and 2) the networking of PCUs required for the entire route.

A very sophisticated piece of electronics, the PCU provides closed loop, variable voltage, variable frequency (VVVF) electrical power for propulsion. The size of the individual PCU is determined by both the vehicle speed and train length of the individual system. But very few PCUs of the size required for high-speed, high-density systems exist today. Furthermore, they require more sophisticated control than typical industrial PCUs.

The number of PCUs employed in the network is of concern since the PCUs are expensive. The absolute minimum number of PCUs is determined

Figure 10.—The Principle of Linear Motors



SOURCE: "Long Term Assessment of Passenger Ground Transportation System Technology," Massachusetts Institute of Technology, 1982.

by either: 1) the number of vehicles simultaneously on a route (since each vehicle requires a dedicated PCU), or 2) the minimum practical spacing due to the problem of distributing VVVF power over large distances—whichever dominates. The basic design issue is that the network of PCUs must consider both the state-of-the-art individual PCUs and the optimum sequential switching schemes, which can be costly. * However, since the state of the art in individual PCUs is advancing rapidly, the overall network design most suitable for a maglev system could change in the near future.

Current Stage of Development of Maglev Systems

In Japan and West Germany, both the attraction and repulsion technologies of levitation have been tested and shown to be operational at an advanced experimental level. In each country, one system has now been discarded, and work has been concentrated on the other (each country rejected the opposite system).

In Japan, the Government is funding the development of a repulsion system by JNR. Although still in the experimental stage, very high-speeds (exceeding 300 mph) have been achieved with small vehicles (5 to 9 tons). The latest vehicle can carry eight passengers, but public demonstrations have not taken place nor are any planned at this time. JNR has now asked Government permission to build a larger scale test track.

The development program sponsored by the West German Government is in a more advanced stage. After success with experimental vehicles, a complete system using maglev vehicles on an elevated guideway was built and operated for several months. A track of about 0.6 miles was constructed in Hamburg in 1979 for the International Transportation Exhibition, on which a two-section vehicle, weighing 26 tons with seating for 72 passengers, was operated at speeds up to 50 mph. Although operated at low speed, the vehicles and guideway employed the same basic technology that is being developed for a 250-mph system. At present, an elevated guideway of 20 miles in length is under construction for the testing of two

* The Budd Co., a subsidiary of Thyssen Henschel, developers of power-conditioning systems for several new locomotives and for the West German maglev system, indicates that the power distribution and conditioning system required for revenue service of the German maglev system will be demonstrated at the Emsland facility. According to Budd, the power distribution and conditioning system at the Emsland Maglev Test Facility includes a network transformer of 31.5 MVA, intermediate circuit transformers of 11.2 MVA each, two rectifiers of 17.2 MW each, two puls-inverter groups of 19.2 MVA each and two output transformer groups for higher frequency operation of 16.0 MVA each. The complex portion of the power distribution and conditioning system is the puls-inverters. At Emsland, each puls-inverter group will use two of these units in parallel. Revenue service application will require 30 to 35 MVA, thus necessitating the use of three or four of the puls-inverters in parallel. According to Budd, the use of these inverters in parallel and series has been demonstrated, as the Thyssen Henschel locomotive unit is composed of smaller capacity inverters configured in parallel and series to achieve 10-MW capacity.

preproduction vehicles. The track will make possible sustained testing at 200 mph and limited travel at speeds up to 250 mph. Evaluations will be conducted by an independent group consisting of the West German Railways (DB), the West German national airline (Lufthansa) and the Federal Government. A likely candidate for initial commercial operation would be a high-speed connection between Hamburg and Hanover airport. Although timescales are vague, West German scientists and developers hope to consider possible future maglev corridors in their *1985* planning. If included in the 1985 Strategic Transportation Plan, construction of a corridor could begin in 1990,[6] otherwise consideration of maglev for application in West Germany would not occur again until the *1990* Strategic Transportation Plan.

Both West Germany and Japan have spent significant amounts of research money over the last decade to bring their respective systems to their current stages of development. The German system is further developed than the Japanese, not because the Japanese have placed less emphasis on research, but because more time is required to develop the technology of the superconducting magnets and cryogenics for the Japanese repulsion system.

Areas of Uncertainty

The Japanese System—Repulsion Maglev

This system is still in an advanced experimental stage. Significant changes in the overall system design are still occurring, from cryogenics to power conditioning to guideway shape.

The technology of superconducting magnets is new and untried in the field of public transportation. Although the cryogenics have not yet been shown to be sufficiently reliable for revenue service, JNR runs about a hundred levitation tests a year on this system. A recent advance in the refrigeration technology (for the magnet cooling) has been its location onboard the test vehicle.

The superconducting magnets, cryostat, and refrigeration are the areas in which continued development will occur.

The West German System—Attraction Maglev

This system is now at the preproduction stage. In the summer of 1983 the two vehicles were to be tested for system performance on 20 miles of guideway built to production system specifications. Speed will be increased progressively to 190 mph, and, for about a half mile on each circuit of the track, at speeds up to 250 mph.

The test facility is located in Lower Saxony, near the Dutch border in low lying, marshy country. It will experience a wide range of weather conditions (–15° to +105° F), and the soil structure is poor from the point of view of track pylon stability.

The vehicles will be operated for 18 hours each day–in 30-minute operating cycles, constantly repeated. Two laps of track (about *48* miles when the track is completed) will be undertaken in 20 minutes, followed by a 10-minute stop.[7]

This program will test vehicle reliability in service by routines of starting, running at high-speed, and stopping repeatedly. A 90-percent availability rate is planned with the vehicles traveling about 160,000 miles in the initial year of testing. Thereafter, additional test miles are to be run assuming completion of the Southern loop of the Emsland facility. Tests are scheduled for completion by late 1985 or early 1986.'

If the test program goes as planned, it should be completed by 1986. It would be unusual if the system performs perfectly on initial testing, but Transrapid is confident that the system will perform to the standards and costs forecast.

Comparison of Attraction and Repulsion Systems

For both systems there are still substantial areas of uncertainty: the ability of each system to operate in multiple units, to reliably meet the performance standards required for revenue service, and construction of the new guideway systems to the close tolerances required are some.

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[6]Discussions, January/February 1983. Dietmar Frenzel, West German Embassy; Udo Pollvogt MBB/ERNO; Horst Hesler, Managing Director, Transrapid International.

[7]Transrapid Consortium, "The Emsland Transrapid Test Facility," 1982.

'Information provided by Transrapid Consortium in initial review of draft OTA document.

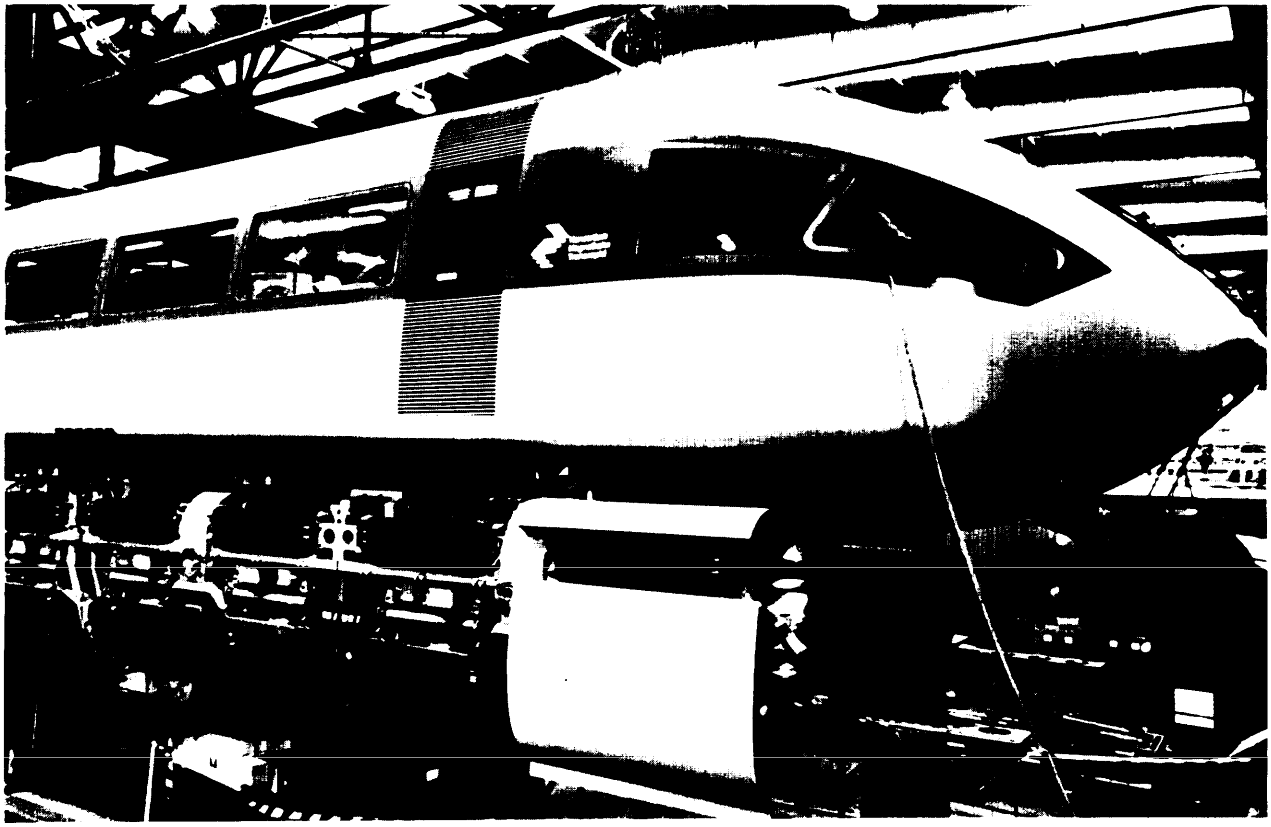

Photo credit: The Budd Co.

Attraction maglev vehicles to be tested at Emsland Test Facility in West Germany

One major difference between the systems concerns the air gap between guideway and vehicle. In the Japanese system, the air gap increases with speed and levels off at about 4 inches, and in the West German system it is about % inch and remains constant. There is disagreement in the scientific community over the significance of gap sizes in terms of vehicle operation.

A second major difference between the systems concerns the magnets on the vehicles. The repulsion system depends on superconducting magnets necessarily cooled to within a few degrees of absolute zero. The attraction system uses electromagnets of developed technology making them closer to deployment for commercial application. So far the superconducting magnets have been tested only under strict supervision and control, and only recently with refrigeration on the vehicle itself. Questions regarding operational and system concerns still remain regarding the superconducting magnets.

In both systems, hotel power* is required on the vehicles. In addition, both systems require power for the magnets. In the attraction system, the power required for the magnets increases with speed, while in the repulsion system, this power is constant. However, the repulsion system requires refrigeration power for maintaining the cryogenic refrigeration for the superconducting magnets. Onboard power plus hotel power for either system are sufficiently low so that it can be inductively coupled from the guideway as the Japanese and West German developers are doing.[9]

*Hotel power includes power necessary to light, cool, and heat the vehicles.

[9]Dr. Robert Borcherts, Research Scientist, Ford Motor Co.

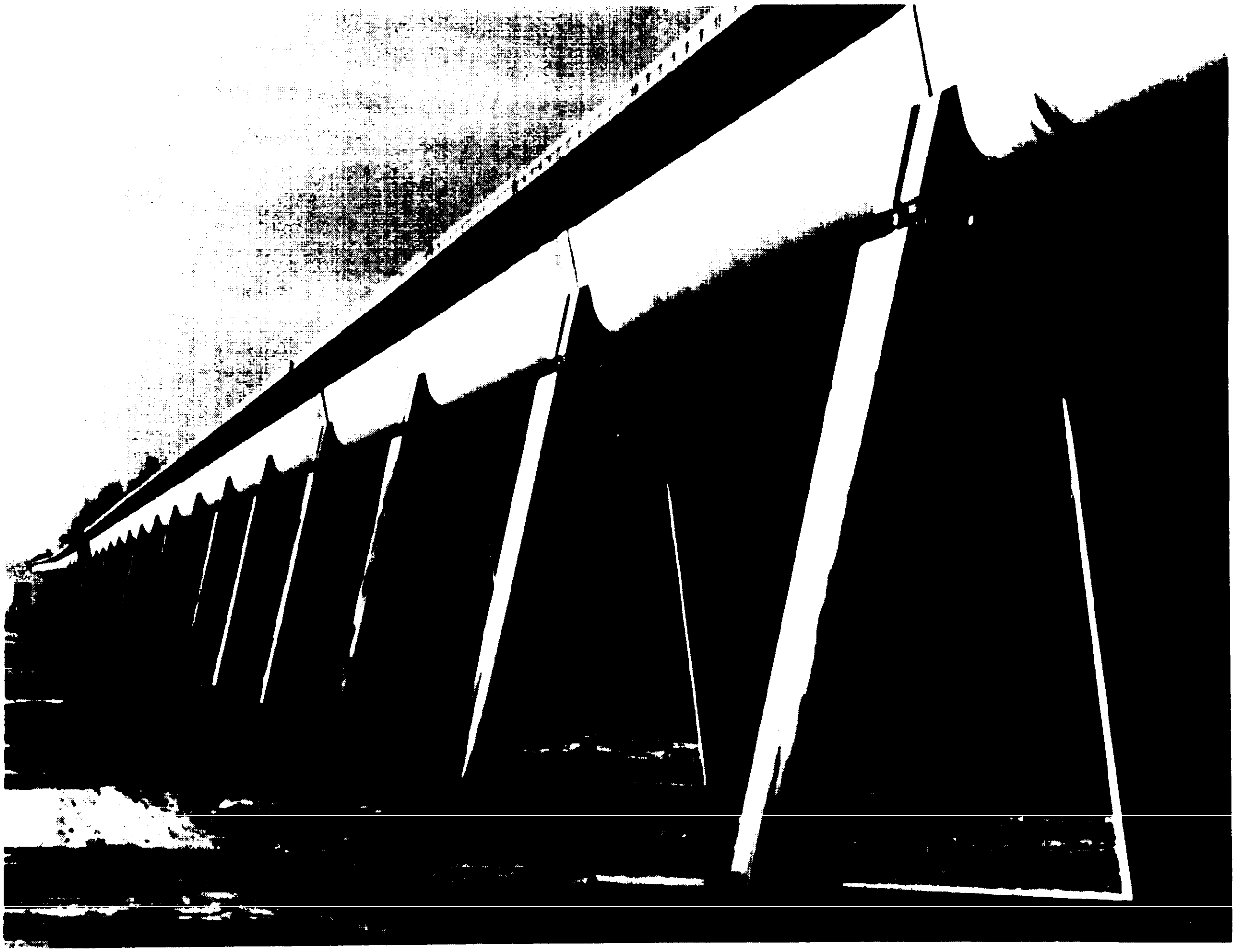

Photo credit: The Budd Co.

Maglev test guideway at Emsland Test Facility in West Germany

Magnetic drag is substantial in the repulsion system, requiring greater propulsion power than the attraction system. Since propulsion power to overcome this drag is relatively independent of speed, and is a significant fraction of total drag (magnetic and aerodynamic) at lower speeds, the repulsion system is much less favorable at speeds under *250* mph.

The next stage in West Germany might have been the construction of a full-scale vehicle for use on a limited length track for test purposes. However, the West Germans have telescoped this stage with the final stage of demonstration of the system under operational conditions. The new track at Emsland is a replica of a section of the proposed guideway and is suited to testing the vehicles at 190 to 200 mph for long periods and for speeds up to 250 mph for short stretches. The vehicles have been constructed of the materials, according to the final design, and by the methods that will be used for production. Nevertheless, questions have to be answered before the system can be said to be fully operational:

- The two vehicles must be shown to meet the performance levels forecast under controlled conditions.
- The system (i.e., vehicles, guideway, power distribution and conditioning system) must

then be shown to continue to perform under operational conditions for a substantial test period, with an acceptable level of maintenance.

The main test schedule provides for 160,000 miles of operation in the initial year of testing with additional mileage anticipated thereafter until test results become available by 1985.[10] Success at this level would undoubtedly lead to full certification in Germany.

Failure in the initial first 160,000 miles of tests could lead to modifications of certain systems or components involving a new cycle of experimental work. This need not take as long as the past development work, since only some of the components would have to be reviewed, however, it would probably delay the project.

[10]Communique from Transrapid International, Apr. 6, 1983.

Chapter 7

U.S. PASSENGER RAILCAR MANUFACTURING

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Chapter 7

U.S. PASSENGER RAILCAR MANUFACTURING

SUMMARY

It is unlikely that a U.S. manufacturer will decide to manufacture railcars, or be able to compete against foreign manufacturers, unless the United States, like other industrialized countries with rail systems and rail manufacturing industries, has a stable, predictable, and planned rail equipment market, one in which orders are spread out in time and in manageable sizes. *

OTA's analysis suggests the following reasons for the decline and demise of the U.S. passenger railcar manufacturing industry:

- the steep drop over the past 50 years in the size of the U.S. intercity passenger railcar market, and in passenger rail's share of the growing travel market, as passengers increasingly chose other modes—particularly air and auto;
- the continuing erratic nature of U.S. urban rail transit orders, exacerbated by the sudden infusion, and later subsidence, of Federal funds for mass transit between the late 1960's and the present;
- the entrance in the late 1960's and early *1970's* of new U.S. aerospace manufacturers drawn in by the dramatic increase in Federal funds, the prospect of a growing mass transit market and by Federal encouragement. This market turned out to be too small to support all the suppliers;
- inflation, sophisticated equipment requirements, and technical difficulties resulted in heavy financial losses for most manufacturers as they sought to fill the large orders generated in the last decade under fixed price contracts with no escalation clauses; and
- the lack of standardized equipment among various transit agencies plus the diverse special features required by them.

The U.S. manufacturing industry was not destroyed by foreign competition. Foreign manufacturers did not enter the U.S. market until most U.S. manufacturers had announced plans to leave the market.

Without exception, the passenger railcar manufacturing industries in Europe and Japan export a small proportion of their production, and most of that goes to countries that do not have production facilities of their own such as Third World countries. The bulk of foreign production is geared to meeting the basic demand for passenger railcars within their home countries.

In practice the market for passenger railcars in the other nations with extensive nationalized systems is closed to outside manufacturers. The national railways, with the approval of the various governments, normally expect to buy equipment from suppliers within the home country, and only buy abroad when the home industry cannot supply what is needed. The governments in those countries have invested heavily in passenger rail networks according to a clear and consistent policy and policy implementation. Thus, the manufacturers in those countries are assured of a stable, predictable market that is effectively closed to outsiders. Manufacturers abroad typically also have a close and continuing relationship with the railways, jointly conducting research and development with them and developing the basic designs.

Few U.S. passenger car orders are expected for the rest of this decade. A recent report shows that, for the 1980's, most of the light railcar purchases have been made, and only orders for 438 rapid railcars have not been placed. * The effect of recent tax increases for urban rail transit purchases, to date, is unknown.

Intercity railcar fleet additions are not anticipated for at least the next 8 years. Today, Amtrak operates some 1,600 cars, 1,000 of which

● The section of this chapter on U.S. railcars encompasses all passenger rail manufacturing markets including intercity, commuter, rapid rail, and light rail vehicles. Typically the term "railcar" has referred to transit cars. In this report, it includes all vehicle categories. The section on EEC countries pertains to intercity cars and also to transit cars. However, full information on transit cars was not obtained.

● Several additional light railcar orders not included in the N. D. Lea report have been or are being placed, according to participants in the OTA Workshop on Railcar Manufacturing.

were purchased in the 1970's. The remaining 600 have been rebuilt at Amtrak's Beech Grove, Ind., facility.

Between 1990 and 2000, the total average annual rail transit orders in the United States are expected to be between 450 and 550, and in the first decade of the next century, the average annual car order is predicted to be no more than approximately 550.[1] Transit accounts for nearly 63 percent of the total current railcar market in the United States. The New York Metropolitan Transportation Authority accounts for 65 percent and the Chicago Transit Authority for 12 percent of the total transit market. Together, New York and Chicago dominate with 77 percent of the total transit market, and more than **40** percent of the total railcar market. Between them, they utilize at least six different irreducible railcar designs. Their plans, or lack of plans, for fleet replacement or expansion and size of order are an important factor in determining the size and shape of any new railcar market in this country.

The construction of several advanced high-speed intercity rail corridors would not add significantly to the fleet. Although this would create *a small surge in orders with construction spread over several years, it would have no major long-term impact on the railcar market.*

[1]N. D. Lea Associates, *Survey of the Railcar Equipment Market, June 1982.*

DISCUSSION

The passenger rail equipment market covers a variety of locomotive and railcar types for a wide range of services. For purposes of this chapter, the passenger rail services are divided into the four broad categories of intercity, commuter, rapid transit, and light rail. Equipment for providing these services includes conventional diesel and electric locomotive-hauled passenger car trains as well as self-propelled cars for intercity, subway, and street railway use. The light rail vehicle (LRV, once referred to as the street or trolley car) also is included in the transit equipment category.

Following is a discussion of the main trends and changes in travel markets, service and supply industries, and institutions that led to the demise of the U.S. passenger railcar industry.

Trends in Travel Demand and Equipment Use

The single most important factor that led to the decline in the passenger railcar manufacturing industry was the widespread introduction and use of automobile and airplane. As people could afford increasingly to purchase and travel by these alternative modes, the demand for intercity travel by rail fell, as did the demand for transit services. Although intercity passenger travel increased by 550 percent from 1929 to the present (table 12), the demand for intercity passenger travel by rail decreased by 65 percent over that same time period. Transit demand decreased 43 percent from 1940 to 1975 as shown in table 13. Changes in reporting occurred in 1975 for transit. A 13-percent increase in originated transit trips has occurred from 1976 to 1980.

The decline in rail travel demand meant a decline in demand for passenger rail equipment as well. At least 10 times as many railcars were in service in 1929 as there are today (fig. 11). New equipment was added to the fleets during the 1930's to replace old railcars and provide high-quality service. This practice continued until World War II when a number of older railcars were brought out of retirement to provide essential cross-country transport. These were retired again at the end of the war.

In 1946, the railroads began to modernize their fleets, and railcar building reached its peak in 1950, although the total number of cars in service continued to decline. The construction of intercity passenger and commuter railcars remained at a low level after the final building surge in the 1940's and 1950's. Thereafter, few intercity cars were built until the Amtrak orders of the 1970's.

Table 12.-Volume of U.S. Intercity Passenger Traffic (millions of revenue passenger.miies and percentage of totai (except private))

Year	Railroads[a]	Percentage	Buses	Percentage	Air carriers	Percentage	Inland waterways	Percentage	Total (except private)	Private automobiles	Private airplanes	Total (including private)
1929 ,	33,965	77.1	6,800	15.4	—	—	3,300	7.5	44,065	175,000	–	219,065
1939, . . .	23,669	67.7	9,100	26.0	683	2.0	1,486	4.3	34,938	275,000	–	309,938
1944, . .	97,705	75.7	26,920	20.9	2,177	1.7	2,187	1.7	128,989	181,000	1	309,990
1950	32,481	47.2	26,436	38.4	8,773	12.7	1,190	1.7	68,880	438,293	1,299	508,472
1960, .,	21,574	28.6	19,327	25.7	31,730	42.1	2,688	3.6	75,319	706,079	2,228	783,626
1970	10,903	5.7	25,300	14.3	109,499	77.7	4,000	2.3	149,702	1,026,000	9,101	1,184,803
1974 ,,,.	10,475	5.9	26,700	15.1	135,469	76.7	4,000	2.3	178,644	1,143,440	11,000	1,331,044
1980p., .	11,500	4.6	27,700	11.2	204,400	82.6	4,000	1.6	247,600	1,300,400	15,000	1,583,000
19811.) ...,,	11,800	4.8	27,200	11.1	201,300	82.5	4,000	1.6	244,300	1,344,000	14,700	1,603,000

NOTE Am carrier data from reports of CAB and TAA; Great Lakes and rivers and canals from Corps of Engineers and TAA; all 1980 and 1981 figures are from TAA data, except rail freight traffic Is by the AAR
[a]Railroads of all classes including electric railways, Amtrak and AUtO-Train
[p]These are preliminary estimates and are subject to frequent subsequent adjustments

SOURCE *Yearbook of Railroad Facts, 1982,* p 33

Table 13.—Trend of Originating Transit Passenger Trips

Calendar year	Railway: Light rail (millions)	Railway: Heavy rail (millions)	Railway: Total rail[a] (millions)	Trolley coach (millions)	Motor bus (millions)	All modes passenger rides/trips (millions)
Revenue passenger rides:[b]						
1940	4,182	2,282	5,464	419	3,620	10,504
1945	7,081	2,555	9,636	1,001	8,335	18,982
1950	2,790	2,213	4,903	1,261	7,681	13,845
1955	845	1,741	2,586	889	5,734	9,189
1980	335	1,670	2,005	447	5,069	7,521
1965	204	1,678	1,882	186	4,730	6,798
1970	172	1,574	1,746	128	4,058	5,932
1971	155	1,494	1,649	113	3,735	5,497
1972.	147	1,446	1,593	100	3,561	5,253
1973.	144	1,424	1,567	74	3,653	5,294
1974.	114	1,435	1,549	60	3,998	5,606
1975.		1,388	1,492	56	4,095	5,643
1976.	86	1,353	1,450	54	4,168	5,673
Linked transit passenger trips:[b]						
1977.	79	1,335	1,425	51	4,246	5,723
1978.	80	1,415	1,506	51	4,406	5,983
1979.	83	1,474	1,569	55	4,746	6,370
1980p	81	1,420	1,513	71	4,774	6,358

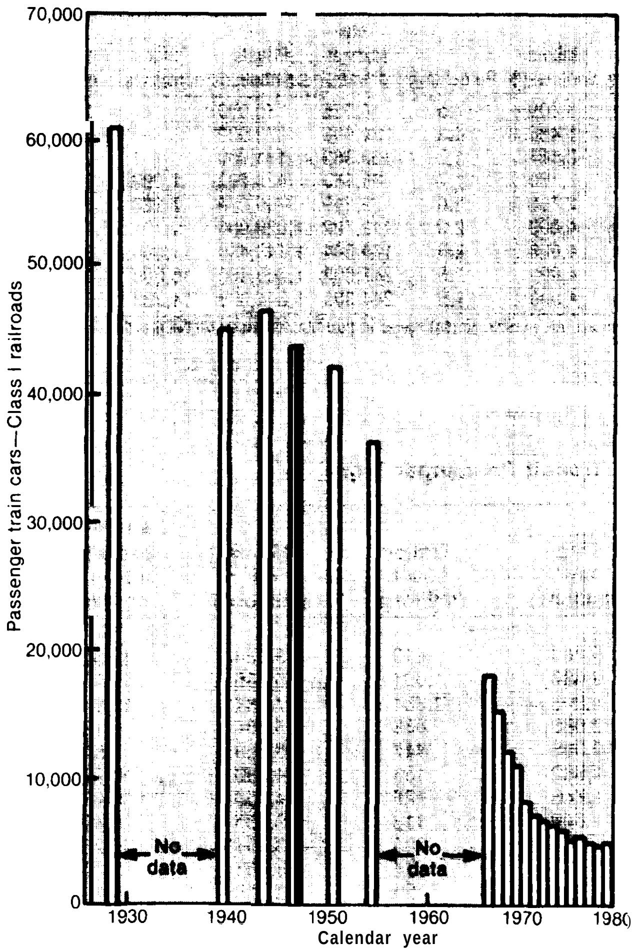
NOTE: Table excludes automated guideway transit, commuter railroad, and urban ferryboat,
[a]Includes cable car and inclined plane beginning in 1975.
[b]"Revenue passenger rides" from 1940 through 1976; "Linked transit passenger trips" beginning in 1977.
[p]These are preliminary estimates andare subject to frequent subsequent adjustments.

SOURCE: *Transit Fact Book* (Washington, D.C.: American Public Transit Association, 1981)

To accommodate the decrease in demand in the 1950's, railcar builders began to shift production to transit cars. Figure 12 charts the trends and numbers of intercity and commuter railcars delivered from 1960 to 1982. As the figure shows, few commuter cars were delivered in the 1960's, and a small number of intercity cars were delivered compared to car requirements of the previous railroad era.

The U.S. railcar market has always been erratic. The fluctuations generally stemmed from the fact that the rail systems, going into operation at different times, initially ordered entire fleets, or large portions of fleets, all at once. Since the average car historically was used up to 30 years before being replaced or overhauled, the only additional orders these companies placed in the interim were those required for any expansion of service. Since

Figure 11 .—Long-Term Trend for Passenger Car Use in Railroad Service



NOTE: All cars, including commuter cars and cars retained bv railroads after the formation of Amtrak (excludes urban transit cars) '

SOURCE, AAR Yearbook of Railroad Facts, 1982 Data and chart compiled by John Bachman

the lines opened at different times with relatively large orders, replacement orders occurred at different times. As will be explained later, however, the phenomenon of huge orders—such as the New York City Transit orders for 1,250 cars did not occur until the infusion of Federal funds, starting in the 1960's enabled transit operators to undertake wholesale and often long deferred modernization of their fleets.

Prior to the 1960's, subway (rapid transit) service operated in five major cities: Boston, Chicago, Cleveland, New York, and Philadelphia. Light rail electric streetcar service flourished for years. Streetcar building, resumed after World War II, remained high as transit companies, then privately owned, reequipped their fleets with the new PCC (President's Conference Committee) type streetcars. However, with the public's growing use of automobiles, and the transition of transit companies to motor bus operations, the production of streetcars was suspended between 1952 and 1972. Heavy railcar deliveries, however, went through a replacement cycle in the early 1970's partly due to increases in Federal funding. Table 14 shows the trends in light rail and heavy rail vehicles owned and leased from 1940 to 1980. Figure 13 shows historical trends in light rail and heavy rail vehicle deliveries from 1960 to 1980. New York City accounts for approximately 6,500 of the 9,500 transit cars in the total existing rapid rail fleet.

Institutional Shifts

As the operations of transit and intercity services suffered growing financial losses after World War II, Federal financial assistance was sought and eventually secured, and ownership passed from private to public hands.

Federal loans for transit cars began in 1961, with $5o million made available for capital needs

Table 14.—Transit Passenger Vehicles Owned and Leased

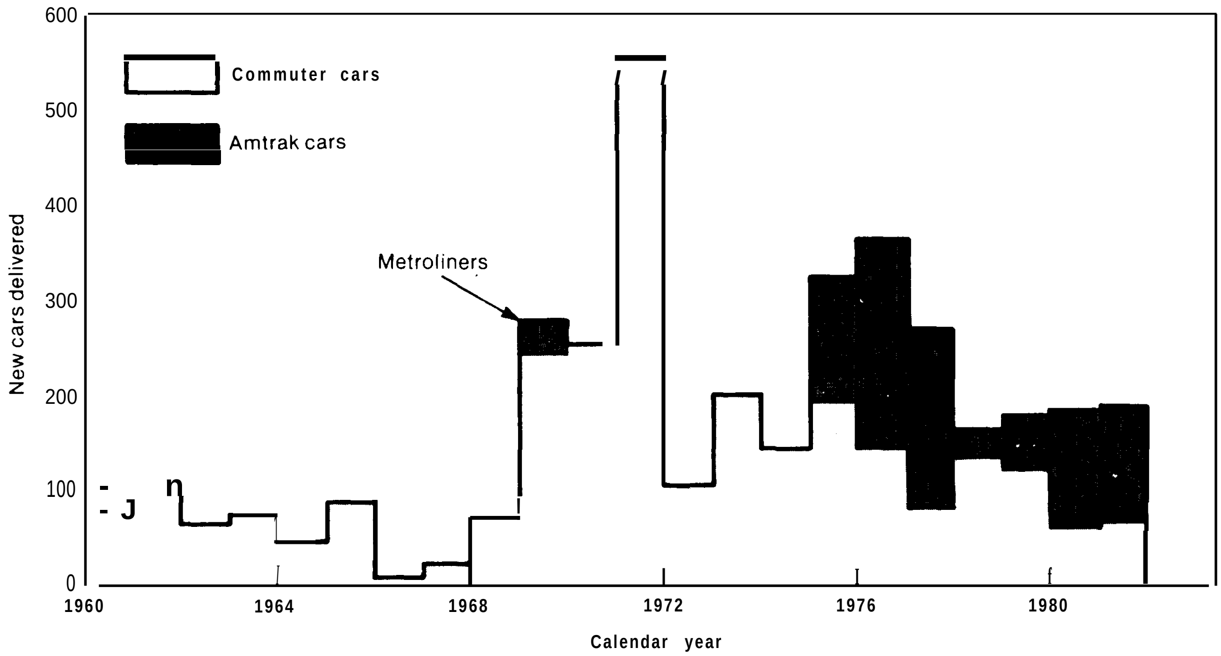
Calendar year	Light rail	Heavy rail	Total rail[a]
1940	26,630	11,032	37,662
1945	26,160	10,217	36,377
1950	13,228	9,758	22,986
1955	5,300	9,232	14,532
1960	2,856	9,010	11,866
1985 ... , ...	1,549	9,115	10,664
1970	1,262	9,338	10,800
1971	1,225	9,325	10,550
1972	1,176	9,423	10,599
1973	1,123	9,387	10,510
1974	1,068	9,403	10,471
1975	1,061	9,608	10,712
1976	963	9,714	10,720
1977	992	9,639	10,674
1978	944	9,567	10,556
1979	959	9,522	10,524
1980 (preliminary) . . .	1,013	9,693	10,749

NOTE: Table excludes automated guideway transit commuter railroad and urban ferry boat.

[a]Includes cable cars and inclined plane cars beginning in 1975.

SOURCE: *Transit* Fact Book (Washington, D. C.: American Public Transit Association, 1981).

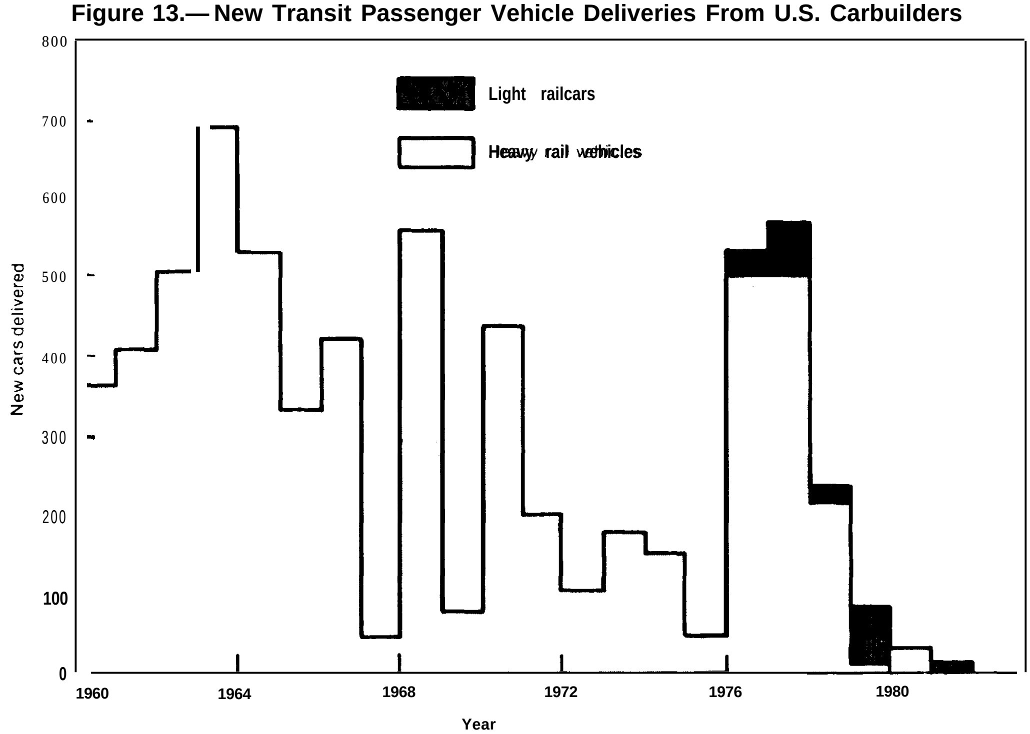
Figure 12.—New Passenger Railroad Cars Delivered From U.S. Manufacturers[a]



[a]French turbo trains, built in the 1970's were not Included in the calculations

SOURCE Compiled by John Bachman

Figure 13.—New Transit Passenger Vehicle Deliveries From U.S. Carbuilders



SOURCE Compiled by John Bachman

and $25 million for demonstration projects. However, the initial loan program was not sufficient to meet the needs of the ailing transit industry and, by 1964, the Federal Government passed the Urban Mass Transportation Act (UMTA), which became the basis for Federal financial assistance to transit operators.

Commuter lines were consolidated into regional operating authorities funded by various local governments and the communities served. Before 1965, eight cities were served by 24 different railroads providing commuter services. Between 1965 and 1982, 15 new operating authorities were formed to serve those eight cities. Conrail's relinquishment of commuter responsibility in 1982 is the most recent institutional change in commuter rail service.

Intercity passenger rail services, initially provided by the Class I carriers, * also experienced significant changes in the late *1950's* and 1960's. Routes were abandoned to the maximum extent permitted by the Interstate Commerce Commission or operated at losses. Concerned about the bankrupt New Haven Railroad, increased population projections along the Northeast Corridor (NEC), and airport congestion, Congress enacted the High Speed Ground Transportation Act (HSGTA) in 1965.[2] Funding and development and demonstration of two types of cars, the Metroliner cars and the turbotrains, for intercity service along the corridor were provided by the act. However, the remainder of the Nation's passenger rail services continued to decline to the point that Congress created the National Railroad Passenger Corp. (Amtrak) in 1970 to maintain an essential core of intercity passenger rail services. Original equipment for Amtrak operations came from the railroads that had discontinued services and joined Amtrak.

The shift from private to public sector passenger rail operations, together with the infusion of Federal funds, had significant implications for the passenger railcar manufacturing industry. Through UMTA legislation, large capital resources became available for buying transit equipment and for financing major extensions to existing systems and construction of new systems. For intercity passenger services, the new funds allowed the rebuilding and replacement of much of the aging car fleet. Table 15 shows the federally financed purchases for rail transit and commuter equipment between 1965 and 1982. Intercity railcar purchases by Amtrak have totaled approximately 1,000 cars and some *320* locomotives.[3]

Federal legislation also made funds available for the construction of several new transit systems, and the entry of new manufacturers from tile aerospace industries was encouraged.[4] According to a General Accounting Office report, "U.S. manufacturers anticipated a boom and entered the market amid forecasts of large, profitable railcar orders. However, the market turned out to be far smaller and more erratic than the companies anticipated. "[5] Entry of new manufacturers into an already small and unsteady market altered the competitive market structure. Figure 14 shows a chronology of major suppliers for the passenger railcar market from *1960* to the present, their market entry and exit dates, and the approximate annual production capacity of each manufacturer. Art R. J. Barber Associates report in **1978** notes that both U.S. and world passenger railcar manufacturers were operating below plant capacity. According to that report, between 1971 and **1977 U.S. passenger railcar deliveries averaged just under 600,** when the capacity of the Pullman plant alone was *700.*[6] According to data provided in a study by N. D. Lea Associates, total foreign railcar orders by U.S. transit agencies between **1970** and **1982** were for approximately *2,300* railcars of which only 19 percent were ordered by 1979. Table *16* shows U.S. and foreign railcar deliveries to the United States from *1971* to *1982.*

***Class I rail carriers are currently defined as line haul railroads with annual operating revenues of $50 million or more effective January 1978. Prior to 1956, the carriers were defined as Class I if they had operating revenues of** *over $1* **million. The revenue level was raised several times between 1956 and 1978.**

[2] *Second Report on the High Speed Ground Transportation Act of 1965* **(Washington, D. C.: U.S. Department of Transportation, September 1967), p. 1.**

[3] "Amtrak's **Second Decade, " draft paper, pp. 10-11.**

[4] UMTA **Legislative Record.**

[5] U.S. **General Accounting Office, "Problems Confronting the U.S. Urban** Railcar **Manufacturers in the International Markets," July 1979, p. 5.**

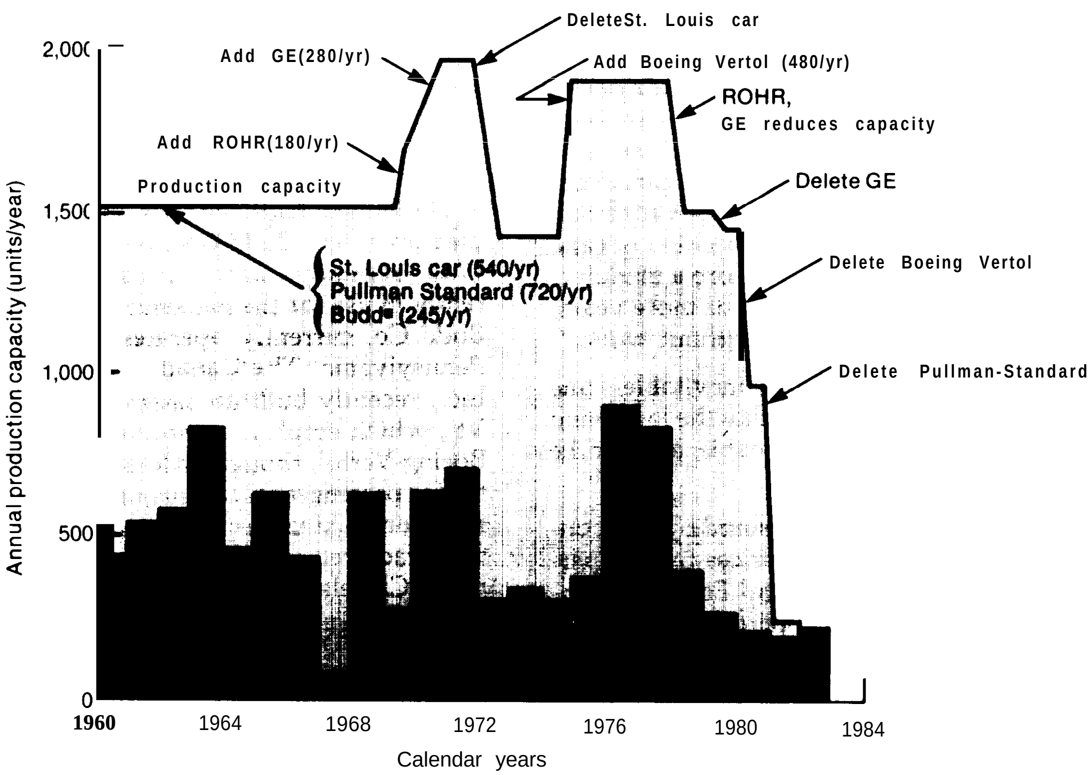
[6] **R. J. Barber Associates, Inc., "The United States and the International Market for Rail Equipment, " prepared for** UMTA, **March 1978, pp. 19-21.**

Table 15.—Federal Transit Commitments (new railcars, by type and fiscal year) (commuter, transit)

Fiscal year	Total	Rapid transit	Light rail	Commuter electric	Commuter diesel	Diesel locomotives[a]
1965	64	64	—	—	—	—
1966	400	400	—	—	—	—
1967	35	—	—	35	—	—
1968	370	226	—	144	—	—
1969	383	260	—	123	—	—
1970	309	—	—	309	—	—
1971	317	—	80	237	—	—
1972	509[b]	420	—	64[b]	25	—
1973	851	650	150	15	36	13
1974	420	200	45	170	5	2
1975	320	140	—	160	20	—
1976	108	—	—	58	50	22
Transition quarter	71	71	—	—	—	8
1977	420	320	48	50	2	9
1978	356	125	141	—	90	23
1979	417	326	—	—	91	19
1980	78	16	26	36		—
1981	310	204	26	—	80	7
1982	538	414	55	21	48	24
Total	6,276	3,836	571	1,422	447	127

[a] For commuter service.
[b] Does not include 21 cars funded in fiscal year 1972 which were subsequently canceled.
SOURCE: information provided by Robert Abrams, Urban Mass Transportation Administration.

Figure 14.—Annual U.S. Production Capacity and Output of All Types of Passenger Railcars



[a] Although not reflected in GAO report, the Budd Co. indicated additions to their capacity from 245 to 465 after 1980.

SOURCE: Compiled by John Bachman, U.S. General Accounting Office, "Problems Confronting the U.S. Urban Railcar Manufacturers in the International Markets," July 1979.

Table 16.-U.S. Passenger Railcar Deliveries, 1971-82 (foreign company deliveries in parentheses)

Year	Light rail	Rapid transit	Commuter rail	Intercity	Total
1982	1 (118)	118 (16)	o (86)	**97**	216 (220)
1981	O (87)	14 (158)	36	100	150 (245)
1980	30 (16)	O (127)		134	239 (392)
1979	71	10 (60)	126 (40)	61	268 (loo)
1978	16	170 (lo)	131	1	318 (lo)
1977	61	500	165 (36)	113	839 (36)
1976	30	500	128	409	1,067
1975		145	127	132 (20)	404 ***(20)***
1974		101	167	—	268
1973		254	169	10 (lo)	433 ***(lo)***
1972	—	34& (46)	376	—	716 **(46)**
1971	—		319	—	405
1971-79 U.S. average annual delivery = 524					

SOURCE: Railway *Age, Passenger Car-Market at* ***a Glance.***

•

The shift to Federal funds brought changes in procurement procedures. More parties were involved in the development and approval of specifications, and financial procedures for obtaining funds.[7]

Lack of escalation clauses in the fixed-price contracts, lack of progress payments, and technical problems which occurred on many railcar orders, compounded by large order sizes, resulted in heavy financial losses for most manufacturers.

Federal funding enabled transit authorities to replace very large numbers of similar cars over a very short time. Thus instead of a series of orders for a relatively small number of cars every year, the pattern changed to one of a very small number of orders each for a large number of cars. This meant that success would absorb a manufacturer's complete capacity for one or more years, while failure would leave him without work.*

What happened perhaps was inevitable—one by one, manufacturers decided that the losses and risks in continuing were unacceptable, and left the industry.

Since 1967, inflation, as measuredly the Consumer Price Index, increased prices by 250 percent. However, the General Rail Equipment Index showed industry prices increasing over 330 percent.[8] Table 17 illustrates the type and number of changes in rail orders that occurred over the past 20 years. Many resulted in initial and sometimes persistent technical difficulties for railcar builders and transit agencies, leading to increases in warranty and protection provisions and car costs. The innovations were developed to improve car performance, increase ridership, and reduce maintenance. However, the innovations were not standardized. All of the reasons listed finally brought about the virtual demise of the domestic passenger railcar manufacturing industry in the late 1970's—at a time when several large new orders were about to be placed.

Current Industrial Base

The United States now has only one prime manufacturer—the Budd Co., owned by Thyssen of West Germany—and four assembly plants currently in use for the passenger rail industry. The Budd Co. currently operates its railcar plant in Pennsylvania. The Canadian firm, Bombardier, Inc., recently built an assembly plant in Barre, Vt., which employs approximately *250* people. Boeing-Vertol, though no longer a prime contractor for passenger railcar manufacturing, maintains a subcontracting business for assembly of foreign manufactured railcars. The General Electric Co. has a Cleveland facility for assembly.

Amtrak maintains its own railcar repair and rebuilding facilities at Beech Grove, Ind., with approximately **1,000** employees. According to Amtrak President, W. Graham Claytor, Jr., Amtrak is bidding competitively with other railcar manufacturers and assemblers only when Amtrak equipment repair needs have been met by the

'U.S. General Accounting Office, op. cit.

***Car prices currently average about $1 million each.**

'Jeffrey Mora, "Factors Affecting Railcar **Costs, " presented at the** *Third National Conference on Light Rail Transit,* **March 1982, p. 2.**

Table 17.-Innovation Matrix for Railcars

	New truck	Air hyd or hyd brakes	Regenerative braking	Solid-state motor control	Cab signals	Automatic operation	Air-conditioning	Nonstandard voltage	Total number of innovations	New carbuilder	Carbuilder without experience in North America
MARTA—Franco Beige		X	X	X	x	X	x	X	7		x
Miami/Baltimore- Budd			X	X	x	X	x	X	6		
MBTA—Boeing LRV	X	X		X			x		4	X	
San Francisco—Boeing LRV	X	X		X	x				4	X	
MBTA—Hawker Siddeley							x		1		
MBTA—Pullman Standard					x		x		1		
San Diego—Duwag U2									0		x
CTA—Pullman Standard					x		x		2		
CTA—Budd					x		x		2		
CTA—Boeing					x		x		2	X	
GCRTA—Pullman Standard					x		x		2		
GCRTA—Breda			X	X	x		x		4		x
PATH—Hawker Siddeley							x		1		
PATH—St. Louis Car							x		1		
NYCTA R46 Pullman Standard	X				x	X	x		4		
NYCTA R44 St. Louis Car					x	X	x		3		
NYCTA R42 St. Louis Car							x		1		
NYCTA R38 & R40 St. Louis Car									0		
PATH—Budd					x	X	x	X	4		
WMATA—Rohr		X			x	X	x	X	5		
BART—Rohr	X	X	X	X		X	x	X	7	X	

SOURCE” N. D. Lea Associates, Benefits *of Railcar Standardization,* February 198

Beech Grove facility. Amtrak seeks to maintain the existing employment level at Beech Grove and hopes to increase overall revenues. It does not anticipate expanding Beech Grove, nor bidding on assembly projects that offer no profit margin.[9] Amtrak currently is assembling the Washington Metropolitan Area Transit Authority order for Breda of Italy. Private sector suppliers argue that Amtrak is competing with them by using Beech Grove.

In addition to passenger car manufacturers and assembly facilities, both the General Motors Corp. and the General Electric Co. manufacture locomotives for passenger as well as freight service. Both manufacturers have a history of foreign export of motive power equipment for freight and passenger service. According to the Barber study, the United States was the world's leading exporter of diesel locomotives in 1975, capturing 72 percent of the world market. Most exports were to Third World countries. However, U.S. exported locomotives accounted for 85 percent of Canadian, 60 percent of Italian, 35 percent of Swedish, and 31 percent of Belgian and Luxembourg imports of diesel locomotives.[10]

Projected Demand

A recent report by N. D. Lea Associates outlines projected U.S. demand for transit (light and heavy rail) and commuter cars from 1980 to 2010. Table 18 shows the results of this market survey. Fleet replacement projections assume a life expectancy of 25 years; however, many railcars in the past have exceeded that life expectancy by as much as 25 years, although rebuilding was required. According to the Lea report, for the 1980's most of the light railcar bids have been awarded, and only orders for 438 heavy railcars remain to be placed. Between 1990 and 2000, the total aver-

[9] Interview with W. Graham Claytor, Jr., President of Amtrak, Feb. 10, 1983.

[10] R. J. Barber Associates, Inc., op. cit., p. 7.

Table 18.—Projected Passenger Railcar Demand

Car type	1980	1985	1990	1995	2000	2005	2010
Transit:							
Light rail	497 (76)	233 (35)	–	45	230	274 (74)	233 (35)
Heavy rail	1,450 (242)	1,175 (200)	804	2,717	1,806	1,042	1,609
Commuter	696	323	135	421	515	1,099	869
Total replacement (new starts)	2,643 (318)	1,731 (235)	939	3,183	2,551	2,435 (74)	2,711 (59)
Annual average	528 (63)	346 (47)	187	636	510	483 (15)	542 (10)

NOTE: Parentheses Indicate fleet expansion and new starts. All other numbers indicate replacements.

SOURCE: N. D. Lea Associates, Survey *of U.S. Railcar Market 1967,* June 19S2.

age annual car building orders are estimated to be approximately 470; in the first decade of the 21st century, the average annual car order will be approximately **560.**

Participants in OTA's workshop indicated that the assumptions underlying the Lea report may be overly conservative. Several additional small light railcar orders are expected in California. These projections, it should be stressed, assume current funding levels and practices. For example, New York—according to a workshop participant-could, in the next 10 years, replace another 1,000 cars but does not have the money to buy them. A number of transit agencies that are not planning now to order new cars would do so if they had the funds. Thus, according to transit operators, the potential market could be larger than the market actually projected.

Some experts in the field estimate that with a rational procurement system and a reasonable allocation of orders among manufacturers, the market of 470 cars per year projected for the 1990's could sustain several medium- or small-sized manufacturers.

Additions to the intercity railcar fleet are not anticipated for at least 8 years, since much of the current fleet was replaced in the *1970's.* At its inception, Amtrak acquired 2,000 cars. Today it operates 1,600 cars, 1,000 of which have been purchased in the last decade. The remaining 600 have been rebuilt at Amtrak's Beech Grove facility or by contractors. For the near term, Amtrak plans undertaking prototype development of new cars for their eventual fleet replacement. To minimize annual capital requirements, replacement is planned at 40 to 60 cars per year, with a typical 40-year lifecycle for the fleet. According to Amtrak officials, their plans are sensitive to changes in market conditions and technology .[11]

At current levels of demand, the market for railcars in this country could support a $400 million to $500 million per year industry for the 1990's, with perhaps a $100 million annual increase in the next century, assuming prices remain constant. The addition of several high-speed corridors would add cars to the demand base, with construction spread over several years though it is unlikely that such additions would change the overall market structure significantly.

Foreign Passenger Railcar Manufacturing

The European and Japanese railway equipment construction industries historically focused nearly all their efforts on meeting domestic needs. Until recently, with few exceptions, they have exported rail equipment only to those countries with no manufacturing capacity of their own. Foreign exports of rail equipment continue to account for only a small share of foreign production. Their entrance in the U.S. market occurred primarily when U.S. manufacturers were announcing plans to leave in the late 1970's.

The national railway systems, which the foreign manufacturing industries support, are subsidized in accordance with explicit and consistent national policies that regard passenger rail service as a vital part of the national transportation system. In these countries, the passenger rail service and the rail equipment manufacturing industry function not as separate industries, but rather as two closely related and mutually supporting elements of

[11] Questions raised for Amtrak response, Feb. 10, 1983.

what is, essentially, a single national passenger rail enterprise.

Japan

Five major companies supply the needs of the railways in Japan for locomotives and passenger cars. The major exporting companies are Hitachi, Kawasaki, Mitsubishi, and Tokyu.

It is the practice in Japan for the purchaser to have a list of suppliers who have shown that they can meet the specifications and production rates likely to be desired. Procurement is then by competitive tender from the list of authorized suppliers. However, in recent years orders have been allocated among the available Japanese suppliers so that they all have been able to maintain an economic production rate. Japanese National Railways (JNR) has been a major buyer in the last 5 years, requiring an average of 330 commuter cars and 94o intercity vehicles per year (table 19).[12]

Between 1979 and 1982, U.S. transit agencies have ordered 625 cars from Japanese firms.[13] In addition the Japanese Rail Technology Corp., a subsidiary of JNR, is conducting preliminary engineering feasibility studies of several U.S. corridors for provision of high-speed intercity rail service similar to that provided in Japan.

The European Economic Community (EEC)

Over the period 1972-75, exports represented about one-fifth of total equipment production of EEC countries (see table 20). Only 5 percent of production was exported to other EEC countries, usually to those without manufacturing capability. The remainder of exports (14 percent of total railcar production) went to countries outside the EEC. Clearly, internal demand for equipment during that period was satisfied by national suppliers; exports were a relatively small proportion of production and were concentrated on markets outside the EEC.

Within the EEC, certain firms specialize exclusively in the production of one type of railway equipment while others produce the entire range. Many firms are diversified and active in areas outside the railway industry. Especially in the traction sector, the larger firms are subsidiaries of major national consortia. On the other hand, many of the firms are private, particularly those concerned with hauled vehicles. In Italy and in Great Britain, the largest firms are State owned.[14]

In the construction of intercity passenger vehicles, the majority of the work in the EEC is carried out by small- and medium-sized firms. In 1975, there was substantial and sustained demand for passenger cars in EEC countries (see table 21). Exports were generally around 3 percent of production, although France built up exports from 4 to 32 percent by 1975. The major part of railcar construction was commissioned by the national railways, but a substantial part of the self-propelled vehicles were needed to replace worn out equipment on transit systems and for limited construction of new systems. Table 22 shows the construction of railway passenger vehicles for EEC countries between 1965 and 1975.

In West Germany, most of the firms are incorporated in major industrial groups, including four

[12]Discussions with Japanese National Railways, January 1983.
[13]N.D. Lea Associates, *Railcar Market 1967-1982.*

[14]*Report on the Railway Rolling Steel Industry* (Brussels: Commission of the European Communities, 1977).

Table 19.—JNR's Purchase of Rolling Stocks (number of cars)

	1974	1975	1976	1977	1978	1979	1980	1981	Average per year
Electric MU cars:									
Commuter	72	175	247	177	165	183	190	200	176
Intercity	645	512	282	558	891	322	430	520	520
Shinkansen	462	96	211	190	127	120	156	296	208
Diesel MU cars	34	2	32	20	111	322	217	204	118
Coaches	100	60	151	285	356	300	307	224	223
Total	1,313	845	923	1,230	1,650	1,247	1,300	1,444	1,244

SOURCE: Ichiroh Mitsui, Japanese National Railway representative, Washington, D.C.

Table 20.-Community Exports and Intra-Community Trade

Stock	1972 Value x.u.a.	1972 Percent exports Tot. Wed.	1973 Value x.u. a.	1973 Percent exports Tot. prod.	1974 Value x.u.a.	1974 Percent exports Tot. prod.	1975 Value x.u.a.	1975 Percent exports Tot. prod.
Locomotives:								
Total	72.1	6.1 %	57.8	4.7%0	64.7	4.80/o	44.8	3.0
Intra CEE.	3.4	0.3	7.0	0.6	4.8	0.4	3.9	0.3
Extra CEE	68.7	5.8	50.8	4.1	59,9	4.4	40.9	2.7
Multiple units railcars:								
Total	14.3	1.2	34.8	2.8	42.1	3.1	52.7	3.5
Intra CEE	8.4	0.7	16.9	1.4	21.1	1.6	24.1	1.6
Extra CEE	5.9	0.5	27.9	1.4	21.0	1.5	28.6	1.9
Vans, carriages, and luggage etc.:								
Total	2.3	0.2	17.0	1.4	18.2	1.3	29.8	2.0
Intra CEE.	0.2	0.02	4.7	0.4	4.5	0.3	1.8	0.1
Extra CEE	2.1	0.18	12.3	1.0	13.7	1.0	28.0	1.9
Wagons:								
Total	187.1	15.8	86.3	7.0	108.0	8.0	152.3	10.2
Intra CEE.	53.5	4.5	30.8	2.5	40.0	2.9	38.2	2.6
Extra CEE	133.6	11.3	55.5	4,5	68.0	5.1	114.1	7.7
Total:								
Total	275.8	23.3	195.8	16.0	232.9	17.2	279.5	18.8
Intra CEE	65.5	5.5	59.4	4.8	70.4	5.2	68.0	4.6
Extra CEE	210.2	17.8	135.4	11.2	162.5	12.0	211.5	14.2
Production total EEC	1,185.7		1,227.7		1,358.0		1,487.9	

Key = x.u.a. = ? ; Tot. prod, = total productivity.

SOURCE: Nisexe 1975—analytical tables of foreign trade.

Table 21.-Passenger Car Production, 1975 (value: million U.A..[a])

	Self-propelled	Hauled	Total	Export	Percentage
Belgium	9.3	1.0	10.3	—	—
West Germany	91.5	52.4	143.9	3.6	3
France	62.4	99.6	162.0	51.4	32
Italy	8.3	24.0	32.3	1.1	3
Great Britain	11.8	14.2	26.0	0.7	3
Total	183.3	191.2	374.5	56.8	15

U. A.–Unit of account for EEC = approximately $1.

SOURCE:

Table 22.—Construction of Railway Passenger Vehicles (including transit)

Year	Self-propelled	Hauled	Total	Index
1963/64 average.	NA	2,486	NA	(118)[a]
1965/66 average.	401	2,112	2,513	100
1967	879	1,891	2,770	110
1970	674	1,549	2,223	88
1971 0	580	1,648	2,228	89
1972	604	1,609	2,213	88
1973	688	1,809	2,497	99
1974	837	1,538	2,375	95
1975	832	1,816	2,648	105

NA = Not available.
a Breed on hauled cars only.

SOURCE: John G. Smith.

that are part of iron and steel groups. In Belgium and Denmark, only one manufacturer produces passenger rolling stock. In France, the majority of the 16 manufacturers concentrate either exclusively or primarily on rail rolling stock. The exception is Alsthom Atlantique, where railway activity represents only 15 percent of the group's total sales. In Great Britain, only British Rail Engineering Ltd. (BREL) (a subsidiary of British Railways) manufacturers intercity railway passenger vehicles. One other company specializes in equipment for transit systems. In Italy, 80 percent of the firms operate exclusively in the railway construction or repair sector. State policy to develop Southern Italy has led to investment by EFIM (a body responsible for State holdings) in the railway equipment construction industry.

For the EEC railway manufacturing industry, of 120 firms involved, 91 employed less than 1,000 people in 1975, and only 12 exceeded 2,000 employees. Of these, only 2 employed more than 5,000 people (Alsthom in France and BREL in Great Britain).

In 1974, the EEC fleet of self-propelled cars was 20,800, and there were 51,400 hauled cars, so that the construction rate represented about a 25-year vehicle life. Very few changes have been made in passenger train service levels since that time. If Government policies regarding the support level for passenger train services do not change, an annual production rate in excess of 2,500 vehicles per year will be required to sustain the fleet.

Under EEC regulations, Governments may support railway systems only in the passenger sector, and then by way of payments to recompense the railway for continuing to run passenger trains that are socially desirable but economically unsound. Each year, the Government and the railway in each EEC country reach agreement on which passenger routes will be supported and on the level of payment. In recent years, there has been virtually no change in the routes to be supported, and argument has centered on the appropriate level of support payment. The payment is based on total costs, including depreciation and interest, and, to the extent that revenues fall short of operating costs, some part of the support payment eventually is used to pay for new passenger vehicles.

Capital investment in passenger vehicles for the railways is controlled by the EEC Governments, but different methods are employed to finance the shortfall between accrued depreciations and purchase price. In the case of British Railways, the Government procures funds and lends directly to the railway, while in France and West Germany the railways raise funds in the open market. To do this, they obtain a Government guarantee of repayment, without which it would be impossible to raise the money.

EEC Governments also aid the railway systems in a variety of other ways that also could be regarded as support payments. In **1980,** such support payments in France totaled **$2.4** billion, an increase of **76** percent from the 1970 level (at 1980 prices).[15] In West Germany in the same year, support payments totaled **$6.2** billion, an increase of $4 billion (175 percent) from the 1970 level (at 1980 prices).[16] In Great Britain, support payments for 1980 totaled $1,2 billion, an increase of $1 billion on the 1970 level (at 1980 prices) .17

Prospects for a U.S. Passenger Railcar Manufacturing Industry

Based on examination of U.S. conditions and foreign markets, reemergence of a U.S. passenger railcar manufacturing industry is not likely to occur unless there is an assured and predictable market. Continued improvements in standardization of U.S. railcars, and continued improvements in procurement procedures also have been suggested as important factors in creating a climate favorable for manufacturer reentry into the U.S. market. However, the first requirement is by far the most critical. Without such a market, which all foreign railcar manufacturers have, no potential American manufacturer is likely to regard making railcars as a profitable line of endeavor.

[15] French National **Railways** (SNCF), *Report and Accounts.* 1980.
[16] **West German National Railways** (DB), *Report and Accounts, 1980.*
[17] British Railways (BR), *Report and Accounts,* 1980.

Appendix

ACRONYMS

Appendix
ACRONYMS

AHSR — American High Speed Rail Corp.
Amtrak — National Railroad Passenger Corp.
APT – advanced passenger train
BR – British Railways
DB – Deutches Bundesbahn (West German Railways)
EEC – European Economic Community
FRA – Federal Railroad Administration
HSGTA — High-Speed Ground Transportation Act of 1965
HST – high-speed train
JNR – Japanese National Railways
LIM – linear induction motor
LRC – light, rapid, comfortable
LRV – light rail vehicle
LSM – linear synchronous motor
maglev — magnetic levitation
NEC – Northeast Corridor
NECIP – Northeast Corridor Improvement Project
NRPA – National Railroad Passenger Act
NSF – National Science Foundation
OTA – Office of Technology Assessment, U.S. Congress
PCC – President's Conference Committee
PCU – power-conditioning unit
SNCF – French National Railways
SWC – Southwest Coast Corridor
TGV – Train a Grand Vitesse–French high-speed line between Paris and Lyon
UMTA – Urban Mass Transportation Act
VVVF – variable voltage, variable frequency

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