Energy-Efficient Transportation: Public Systems

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HIGH-SPEED INTERCITY GROUND TRANSPORTATION

High-speed ground transportation (HSGT)--trains that operate at speeds significantly above 125 miles per hour-are technological reality. Whether using steel wheels on rail to carry the cars, as conventional passenger trains do, or conveying them on a magnetic cushion (maglev), HSGT can be built. Steel-wheel trains running at more than 100 miles per hour were introduced in the United States as early as the 1930s, and high-speed trains have been transporting passengers in Japan and France for more than a decade. Maglev systems are based on principles that have been understood since the early 20th century and have been under development since the mid-1960s. Small-scale, low-speed maglev systems currently operate in Germany and England; high-speed systems are in prototype testing phases in Germany and Japan and an imported version may be built in the United States.

Construction of a HSGT system has been "right around the corner' for at least 25 years in the United States. While France's TGV *(Train à Grande Vitesse)* has been in service for more than 10 years, and Japan's Shinkansen (bullet train)[1] for nearly 30 years, U.S. high-speed train systems have barely advanced beyond feasibility studies and modest research and development (R&D) efforts. The reasons have to do with policy as well as geography and demographics. Both Europe and Japan have densely populated cities that are not far apart. For many years their governments have also strongly supported passenger rail

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[1] Shinkansen simply means new trunk line, but ''bullet (rain' is the name commonly used in English.

systems, plus transit systems linked to intercity rail, while other policies (e.g., high gasoline taxes and expensive airfares) have made air and auto travel less attractive than in the United States. These differences have a critical bearing on the feasibility of HSGT in this country.

HSGT—maglev in particular-has received a good deal of attention and political support recently in this country. A comprehensive transportation law passed in 1991 authorizes Federal support to the tune of $725 million for a demonstration maglev project, and $50 million for smaller steel-wheel-on-rail projects, though not much has been appropriated and spent so far. Both systems have been proposed as candidates for government-backed defense conversion initiatives.[2]

This chapter considers HSGT in terms of its potential contribution to American economic competitiveness and its possibilities for defense conversion. Previous studies by the Office of Technology Assessment (OTA) and others have analyzed HSGT from the standpoint of pollution, dependence on foreign oil, safety, and congestion and delay at airports and on highways.[3] These are significant public policy issues—indeed they are key reasons for considering HSGT among the transportation initiatives the Nation could adopt—but they are mostly outside the analytic scope of this assessment. However, the feasibility of HSGT in the United States is directly relevant to the issues discussed here, i.e., international competitiveness and defense conversion.

Government support is necessary to make HSGT systems feasible, according to recent reports by both OTA and the Transportation Research Board of the National Research Council. OTA said that maglev or high-speed rail systems "must be . . . publicly financed in order to be built' in the United States.[4] The Transportation Research Board said: "It is unlikely that any new HSGT system in a major U.S. corridor would cover its capital and operating costs from farebox revenues.

The studies agreed that the main potential market for HSGT systems is trips of about 100-150 to 500 miles between cities, on heavily traveled routes, and the main competition is air travel. On shorter trips, the studies said, automobiles have a clear advantage, and on longer ones airplanes would likely win out. The most promising U.S. routes for HSGT are the Northeast corridor (Washington-New York-Boston) and Los Angeles to San Francisco, with two more possibilities (Dallas/Fort Worth-Houston and Los Angeles-Phoenix) at present and perhaps a dozen more by 2010.[6] In most of these corridors, it appears the systems could break even only with the unlikely combination of costs at the low end of current estimates, fares that are high compared with current airfares, and ridership at least as great as *all* current air travel in the corridor.[7] For the most likely combination of cost and fare levels, only one corridor (Los Angeles-San Francisco) has enough passenger volume at present to break even, again assuming ridership equals all air travel in the corridor, and only four are likely to

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[2] See, for example, Peter H. Stone, "The Faster Track: Should We Build a High-Speed Rail System?" *The American Prospect,* fall 1992, pp. 99-105.

[3] U.S. Congress, Office of Technology Assessment, *New Ways: Tiltrotor Aircraft and Magnetically Levitated Vehicles,* OTA-SET-507 (Washington, DC: U.S. Government Printing Office, 1991); U.S Congress, Office of Technology Assessment, *U.S. Passenger Rail Technologies,* OTA-STI-222 (Washington, DC: U.S. Government Printing Office, 1983); Transportation Research Board, National Research Council, *In Pursuit of Speed: New Options for Intercity Passenger Transport,* special report 233 (Washington, DC: 1991).

[4] OTA, *New Ways,* op. cit., footnote 3, p. 86.

[5] Transportation Research Board, op. cit., footnote 3, p. 8.

[6] Ibid., pp. 109-110, tables 4-3 and 4-4.

[7] Ibid., pp. 9, 117. The Transportation Research Board study combined capital and operating costs; it defined breaking even as covering both.

by 2010.[8] Hence, the need for government subsidy. Capital costs are a particular obstacle for private financing; HSGT requires large upfront investment in a freed asset with little resale value-an inherently high-risk undertaking.

The need for government subsidy is not an insuperable obstacle. Modern rail systems in other countries have all been built on a foundation of strong government support, though it does appear that high-speed systems may now be capable of paying their own way. If the public benefits of the HSGT systems are great enough—benefits such as environmental advantages and lesser dependence on foreign oil-then the argument for public finding for HSGT and for other supportive government policies (e.g., higher gasoline taxes) could be compelling.

From the standpoint of the systems' contribution to economic competitiveness, a central question is whether they could spur the advance of highly innovative, broadly applicable technologies. A look at the requirements of the industry and experience abroad suggest that development of HSGT in this country would contribute to the support of some advanced technologies, but the effects would probably be helpful rather than crucial. It seems unlikely that technologies associated with HSGT would have the kind of widespread creative effects across many industries that technologies at the core of the computer and telecommunications industries have exerted.

As for employment, judging by experience in Japan and France, even a successful U.S. industry would not create a great many jobs in manufacturing rolling stock and parts-probably a few thousand at most. Construction employment could be more substantial, since more than two-thirds of the total cost of creating HSGT systems is in building the tracks or guideways, but these jobs, as far as local and regional economies are concerned, are short-term. Service jobs associated with the systems (in both operation of the vehicles and maintenance of tracks and guideways) could be permanent and somewhat more numerous than the manufacturing jobs. If HSGT were to attract new travelers, beyond those simply switching from cars or airplanes, these jobs could be net additions to the economy.

The potential for converting defense plants from making weapons systems to manufacturing HSGT vehicles looks limited. Several defense contractors with experience in some of the technologies involved in HSGT (e.g., aerodynamics and light-weight materials) have taken part in small government-led development programs in the United States. Most report that they are unwilling to stake much of their own money to advance this effort. Even for successful international fins, the market for rolling stock is relatively limited and quite variable from year to year. The potential looks brighter for defense firms to supply parts and subsystems in such areas as signal, communication, and control systems, which may be based on military technologies. For large defense contractors with civil engineering capabilities, such as Raytheon, HSGT might offer possibilities in guideway engineering and construction. But commercial competition would be fierce from firms such as Morrison-Knudsen, Bechtel, and ICF Kaiser Engineers, all of which have ample experience in transportation system engineering.

▮ Rail Systems in the United States, Japan, and Europe

Rail transportation, intercity and intracity, is far more significant in Europe and Japan than in the United States. In the late 1980s, rail trips in France were 33 times the number of airplane trips, and in Japan rail trips outnumbered airplane trips 130 to 1; in the United States, airplane trips were

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[8] Ibid., p. 8.

1.2 times the number of rail trips.[9] Some of this difference is explained by the sheer size of this country and the distance between cities. Also, higher U.S. incomes (until recently) allowed Americans to make more long-distance trips than Europeans and Japanese. But these explanations. which may be defined as personal preference for air over rail, are incomplete. Public policy has played at least as large a role.

The mix of transportation modes in a country is affected by access, convenience, and cost, each of which is affected by public policy decisions. In Europe and Japan, rail and air systems are (or were until recently) operated by single State-owned or highly regulated firms. Government ownership or control of both systems meant that policymakers could weigh decisions on which to support by the same criteria. For example, decisions in favor of rail over air may have been influenced in part by these countries' reluctance to increase their dependence on foreign oil. The reality of foreign oil dependence in the United States did not begin to take hold until the 1973 oil embargo, some 15 years after the National Defense Highway Act set the fundamental direction for the U.S. transportation system in the post-World War II era.

In both Europe and Japan the commitment to and subsidies for passenger rail service have been strong. Some of these systems were operated at heavy losses; Japan Railways, before its privatization and division in 1986, had debt equal to one-half of the Japanese Government's budget.[10] Although government support for the railways of Europe is less extreme, these systems also receive extensive support, including direct operating subsidies. In the United States, Amtrak's operating subsidy has been relatively modest and has continuously diminished. Note, however, that most countries operating HSGT systems report that they are profitable--after the initial government investment in research, development, and infrastructure. Amtrak's moderately high-speed Metroliner corridor is also reported to be profitable.

Aside from direct subsidy, rail travel in Europe and Japan has been indirectly subsidized by tight restrictions on domestic air travel (limited numbers of flights and high ticket prices) and large taxes on gasoline, which tend to discourage both auto and air travel. The United States, on the other hand, has not regulated airfares for over 10 years and limits total flights mainly for safety purposes, when necessary, not for transportation policy reasons. U.S. gasoline taxes are extremely light compared with those in other industrialized nations; prices at the pump are one-third to one-quarter those in Japan and Europe.

The Federal Government has long been heavily involved in building air and highway infrastructure. In the past, general revenues were used to build airports and pay for air traffic controllers and their equipment; but the Airport and Airway Trust Fund, fed by user fees, began to cover Federal spending on airport improvements in the 1970s and, more recently, the air traffic control system. Federal highways were once funded largely through general taxation as well, but the National Highway Trust Fund paid for the multibillion dollar interstate system that was launched in the 1950s. Most States fund their road construction through gasoline taxes and airport investments through landing and other fees.

Railroads got their share of Federal largess in the last century. Rail systems in the West received enormous government support in the form of land grants; East Coast rail companies got government help in the forms of monopoly franchise awards and right of way acquisition through the Government's right of eminent domain. Although this government assistance was critical to their early development, rail systems today have no trust

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[9] Data from *Europa World Yearbook* (London: Europa Publications, 1991). Japanese data include only Japan Railways hips (excludes private railroads). Data for the United States includes commuter railroads as well as Amtrak passengers.

[10] Michael Selwyn, ''Jap~ Speed Is of the Essence, ' *Asian Business,* June 1990, p. 66.

fund of their own nourished by user fees, comparable to the airport and highway trust funds, to support infrastructure improvement. However, Congress has authorized spending from the highway trust fund for development of high-speed ground systems, maglev in particular.[11]

In contrast to Europe and Japan, with their continuing legacy of government support for and heavy ridership of trains, U.S. public policy related to transportation customs would have to change for HSGT to succeed. Riders would need to be drawn from the most advanced airline system in the world—advanced not only in miles flown and area covered but also in formidable marketing capabilities, including price wars that wipe out weaker competitors.[12]

Nevertheless, there are signs that HSGT systems may be coming closer to fruition in the United States. So far, Federal funding for HSGT has been small. However, foreign governments may indirectly subsidize early ventures in the United States. If the Texas TGV project is built, foreign financing will play a large role, with subsidies coming in part from the French Government-owned Credit Lyonaise (see box 8-A). Presumably, the purpose of the French investment is to sell the French system and get in on the ground floor of an emerging market. If HSGT progresses in the United States, it may be unrealistic to expect that foreign governments will continue to provide financial subsidies and patient capital to the projects. Federal or State Government relationships with railroads and airlines more like those in Europe and Japan are likely to be the condition for a substantial HSGT system in the United States.

HSGT in Europe and Japan

European and Japanese developments of HSGT have been extensive. The French TGV is the fastest steel-wheel-on-rail system in the world. With two lines in operation and more planned, TGV is in full swing. France is also aggressively pursuing foreign markets, e.g., Korea and the United States. In North America, TGV technology is marketed through Bombardier of Canada, whose French subsidiary was involved in the original development of the TGV.[13]

Germany's steel-wheel high-speed rail, the Inter City Express (ICE), entered revenue service in 1991 between Hamburg, Frankfurt, and Munich. Besides high-speed conventional rail systems, Germany has developed maglev as well. The German Transrapid system is closer to commercialization than any other maglev system and is the one proposed for the Orlando maglev demonstration project (see box 8-A). Using attractive magnetic force generated by conventional electromagnets, Transrapid reduces some technical difficulties of building the vehicle (see box 8-B). However, because Transrapid operates with such a small gap between the vehicle and the guideway (about 3/8 of an inch), extreme accuracy is required in constructing the guideway. Such a tight tolerance may not be achievable without drastically inflating costs.[14]

HSGT systems of various kinds have been developed in Spain, Italy, Sweden, and the United Kingdom, as well as Germany and Japan. The U.K. and Swedish systems have tilting trains that can be used at higher speeds on existing or upgraded tracks, in contrast with TGV and ICE, both of which demand new, straighter rights-of-way and dedicated rail track for extremely high-

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[11] The Intermodal Surface Transportation Efficiency Act of 1991, Section 1036.

[12] In early 1993, *after* over 2 *years* of recession followed by weak recovery, even the major airlines were in financial trouble; price wars were damaging them as well as weaker companies. However, assuming recovery in air travel, in the long run it may be more feasible to build maglev systems as complements to airlines than as competitors. Japan Airlines has long taken an interest in maglev as a way to connect airports with downtown areas.

[13] Bombardier, Annual Report, 1991.

[14] New York State Energy Research and Development Authority, *Technical* a& *Economic Maglev Evaluation,* June 1991.

Box 8-A—The Orlando Maglev and Texas TGV systems

Orlando, Dallas-Fort Worth, San Antonio, and Houston are likely to be the first places in the United States to have HSGT systems. The Orlando project, using the German Transrapid maglev system, is limited to a 14-mile single guideway with only one vehicle, connecting the Orlando airport to Walt Disney World hotels. The project planned for Texas, using the French TGV steel-wheel-on-rail technology, will be a full-scale transportation system connecting major cities and points between with 620 miles of track. Instead of complementing air service, as the Orlando project will do, the Texas TGV will be competing for passengers with airlines. Both systems involve consortia of foreign and domestic firms and will use a mix of foreign, domestic, and Federal and State Government financing.

The Texas project began in 1989 with a franchise award from the State Legislature to an international team headed by the U.S. firm Morrison Knudsen and including foreign rolling stock companies (Bombardier of Canada and GEC Alsthom of France) and some foreign financial interests, such as the French Government-owned Credit Lyonaise. Preliminary work, including environmental studies, was underway in 1992.[1] Assuming the project goes forward, total costs are expected to be $5.8 billion, of which about $3 billion would be for construction of the guideways and stations. Most of the spending will be in the United States. Procurement of rolling stock **and signaling, train control, and electrical power equipment had** not yet been worked out in late 1992, but it was expected that a considerable amount would be from U.S. firms.

The first line, linking Dallas-Fort Worth and Houston, was projected to open in 1998, with San Antonio-Dallas links to be completed by 1999.[2] The Dallas-Houston line will compete directly with southwest Airlines, which flies between Houston and in-town Love Field in Dallas. Southwest has argued vehemently against the project claiming that tax-free industrial development bonds (IDBs), which the backers of Texas TGV hope to use for financing some $2 billion of the project, are an unfair government subsidy.

It is by no means certain that the Texas TGV will get permission to use IDBs, since the Federal tax code limits the amounts States may issue.[3] The reason for the limits is that the Federal Treasury is the biggest loser of revenue when tax-free bonds are issued, since the Federal Government has higher income taxes than States (indeed, the State of Texas has no income tax). Railroad construction, unlike airport construction, is counted against States' IDB quotas. Proponents of the Texas TGV, as well as backers of other rail systems, argue that the code should be changed to treat railroad construction in the same way as airport construction.

The Orlando project is far more limited in size than the Texas TGV but more daring in its application of new technology. it promises to be the first high speed (300 kilometers per hour) commercial maglev in the world. Maglev Transit, Inc., an international consortium of U. S., German, and Japanese firms, plans to build the system at a projected cost of $622 million, of which Federal funds will supply a substantial part. Congress has approved a contribution of $98 million to the project, from the mass transit account of the Highway Trust Fund. The rest will come from the members of the consortium.

Construction costs are expected to account for $300 million and vehicles for **roughly another $100 million. Although the U.S. content of the project has not yet been fully worked out, Maglev Transit officials expect it to be substantial. Florida has been guaranteed that at least $100 million of work on the project** will be within the State. However, the vehicles will most likely be built in Germany. Part of the Federal Railroad Administration's certification of vehicle states t hat the vehicle must have the exact specification of the prototype vehicle operating in Germany.

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[1] For example, some dairy farmers and cattle ranchers opposed the project on grounds that noise from passing trains might scare their animals, causing weight loss and lower milk yields. The Issue Is under study.

[2] In December 1992, backers asked for a year's delay because funding was not yet assured.

[3] States are limited to issuing no more than $150 per capita in IDBs for projects other than airports, which have a special exemption.

Box 8-B--Maglev Systems[1]

In a maglev train two things must be achieved: the train must float and it must move. For the lift, there are two approaches; one uses the attractive forces between magnets to pull the train upwards, the other pushes the train up by magnetic repulsion.

The first approach, used in the German Transrapid system, is electromagnetic suspension (EMS). Electromagnets on the train are attracted to the metal guideway from below; in practice, the sides of the train wrap around underneath the guideway beneath the body of the train, effectively lifting the train. The arrangement is potentially unstable. If the gap between the magnet and the rail becomes too large or the magnetic force too small, gravity wins and the train drops, but if the gap becomes too small or the magnetic force too strong, the train will stick to the guiderail and movement will be impossible. (Think of trying to hang a pin beneath a small bar magnet without dropping it or letting it jump up onto the magnet.) To achieve steady suspension, the magnetic attraction is continuously adjusted by varying the current to the electromagnets on the train, in response to information from sensors measuring the distance between the train and the guideway. Because the gap is so small, the guideway must be very smooth and laid to exacting specifications: there must be no more than a few millimeters of vertical variation along a length of 25 meters of track.

A second approach, based on repulsion, is electrodynamics suspension (EDS). It uses the fact that when a magnet is moved over a conductor such as a coil of wire it induces a current in it. The current in the coil itself creates its own magnetic field opposing the first one. In an EDS train, the magnets are on the train and the induced currents flow in specially shaped conducting portions of the guideway. These currents produce a magnetic field opposite to that of the train's magnets, so that the fields repel each other and the train is pushed upward away from the track. Unlike EMS, this arrangement is stable, since if the train and the track move closer to each other, the repulsion gets stronger, and the train is pushed away again, while the force of gravity acts to keep the train from moving too far upward away from the track. However, the effect depends on the train's moving, as it is the motion of the train's magnets across the metallic guideway that sets the current flowing and hence produces the opposing field. An EDS train therefore needs wheels to roll on until it is going fast enough for the electromagnetic effect to lift it. Another complication is that the electromagnetic fields are stronger than in EMS and are not as contained within the coils of the train, so the chance of passenger exposure is considerable. However, the Japanese EDS system has direct current fields, which have not been implicated in the possibility of adverse health effects; it is the effects of alternating current fields that are in question. Still, shielding is an issue since the strong static magnetic field from the EDS system could affect some prosthetic implants and pacemakers.

EDS requires stronger fields than EMS, and is only practical using superconducting magnets. This point was first grasped in the early 1960s by two Brookhaven National Laboratory scientists familiar with the use of superconducting magnets to focus particle accelerator beams. Thus maglev is often described as a U.S. invention, coming from one of the Department of Energy's large national laboratories.

Although other things could push the floating maglev train along-turbofans, for instance--prototypes and designs today all use linear electric motor technology. This works like a familiar AC rotary motor that has been unrolled. The variable electromagnets that form the stator, the stationary part that surrounds the rotating coil of atypical electric motor, are laid flat along the guideway, while coils on the train play the part of the rotor. The guideway magnets are fed an alternating current of a carefully controlled frequency that varies the direction and strength of the force they exert on the magnets of the passing train, pulling them forward as they approach and then pushing them onward as they pass. Electromagnets on the track are switched off behind the train, while the next section of guideway ahead is activated. The train surfs along as it were on a wave of magnetism.

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[1] Drawn from Transportation Research Board, *In Pursuit of Speed*, Special Report 233, 1991; Gary Stix, "Air Trains," *Scientific American*, August 1992; U.S. Congress, Office of Technology Assessment, *New Ways: Tiltrotor Aircraft & Magnetically Levitated* Vehicles, OTA-SET-507 (Washington DC: U.S. Government Printing Office, October 1991); New York State Energy Research and Development Authority, *Technical and Economic Maglev Evaluation*, June 1991.

speed operation. Tilt train technology allows car bodies to tilt over their truck so that passengers remain upright in their seats and comfortable through turns at high-speed. This incremental change in technology can yield significant reductions in travel time. Although very high-speed systems like TGV offer much greater time savings, they also require much greater up-front investment and preclude sharing track with freight and slower passenger trains. Amtrak is considering the purchase of tilting trains from Sweden for use in the Northeast corridor from Washington to Boston.[15] Along this route trip times between New York and Boston might be cut from 4.5 hours to slightly under 3 hours.[16]

Japan has more experience with HSGT than any other country. Its Shinkansen began running between Tokyo and Osaka in 1964 and by all accounts has been profitable, even though Japan Railways as a whole ran enormous losses before being privatized in 1986. Shinkansen technology has undergone continuous improvements and the system was recently expanded. Japan also has an active maglev program, which originated in the 1960s. The major current project is sponsored by the Japanese Railway Technical Institute (JRTI), which is funded in turn by the Ministry of Transportation and several major industrial firms.[17] This project, which uses repulsive magnetic force created by superconducting magnets on board the vehicle, began with a 14-mile test track in Kyushu; a much longer test track is under construction and is planned to form part of an operating line. An alternative maglev effort, HSST, uses technology similar to the German Transrapid. It has been underway since 1974 and is closer to commercialization than the JRTI system. In fact the basic HSST technology was originally developed by the Germans and then licensed to Japan Airlines when the Germans decided to pursue only the Transrapid technology.[18]

Benefits and Costs of Developing HSGT Technology at Home

Since other nations, principally France, Germany, and Japan, already have commercially-proven high-speed steel-wheel systems and prototype maglev systems near commercial operation, what are the advantages of developing and building the systems in the United States versus importing them from abroad, or possibly licensing foreign technologies? The import option may reduce costs, because foreign firms and governments have already absorbed the cost of development, and it lessens risks, since foreign companies are experienced in building the systems. The only high-speed lines progressing toward construction in the United States (those in Texas and Florida) involve European technologies and firms--in both cases, in joint ventures with U.S. firms. Other nations also have some interest (e.g., Sweden) in the U.S. market, which is seen as potentially rich despite the generally guarded tone of the feasibility studies.[19]

Possible benefits of the domestic option are the creation of high-quality jobs, development of advanced technologies that could have wide application, productive use of resources formerly devoted to defense, and the generation of a competitive, knowledge-intensive industry in the

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[15] Joe Dougherty, "High Speed Tilting Train Headed for Northeast Corridor," *Passenger Transport*, Dec. 2, 1991, p. 1. Amtrak began testing tilt trains on the Washington-New York segment in early 1993.

[16] As part of a Northeast corridor improvement program, the last section, that between New Haven and Boston, was expected to be electrified by the end of 1993.

[17] Before its breakup and privatization, Japan Railways directly funded maglev research.

[18] As noted, Japan Airlines is interested in maglev as a connection between airports and city centers.

[19] See, for example, Larry Johnson and Donald Rote, *Maglev and High Speed Train Research in Europe: A Trip Report* (Chicago, IL: Center for Transportation Research, Argonne National Laboratory, July-August 1989).

United States. The question is how likely, and how large, these benefits may be.

DEVELOPMENT COSTS

Most of the costs of building HSGT systems are in construction, but research, development, and demonstration (RD&D) of the technology takes more than a trivial investment. Although safe, reliable systems have operated abroad for years, developing a first-class competitive high-speed steel wheel system in the United States would probably involve more research into braking technologies, wheel-rail dynamics, electric current collection techniques, propulsion, switching, and controls systems. For maglev, research is needed in low-cost guideway construction, switching systems, noise control, and, for systems that use on-board repulsing magnets, shielding options to limit passenger exposure to electromagnetic fields.[20] Coordinated research into lower materials and construction costs, communication and automation technologies, and better understanding of the health effects of electromagnetic fields would benefit both systems.[21] OTA has previously estimated total RD&D costs for a domestically developed maglev system, including the construction of prototype vehicles and a short test track, at about $800 million to $1 billion.[22] An estimate of costs for a high-speed steel wheel demonstration system, based on the experience of the French TGV and the German Transrapid and ICE, is much the same.[23] The Japanese Shinkansen, a more mature technology that has developed incrementally, is a less useful guide to what development cost might be today.

It is highly unlikely that private funds will pay for all of this; indeed, there is already legal authority for a contribution by the Federal Government of $725 million over 6 years for maglev prototype development and $50 million for other forms of HSGT (however, little actual funding has yet been provided; see the discussion below). The French Government paid for most of the TGV development costs, while the costs of developing the German Transrapid and ICE systems were shared by government and industry. For Transrapid, a consortium of firms paid an increasing share as the project progressed, starting in the mid-1970s with the Ministry of Transportation paying nearly the full cost and ending with private industry paying about two-thirds. However, all the firms that paid large development costs had government assurances that, if their efforts were technically successful, the government-controlled railway system would buy the finished product.

EMPLOYMENT EFFECTS

Most of the jobs generated by the building of new HSGT systems would be in construction. The overwhelming share of initial system costs—65 percent or more-is for guideway or tracks, including power and communication equipment. Rolling stock accounts for an additional 10 to 20 percent of costs, and the rest is spent mostly on right-of-way acquisition, design and management of construction, and facilities.[24] For example, the $3-billion track building project envisioned for the Dallas-Houston-San Antonio route might create 11,000 jobs in the construction industry for

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[20] OTA, *New Ways*, Op. cit., footnote 3, pp. 72-73, 81-82.

[21] Ibid., p. 94.

[22] Ibid., p. 9.

[23] William Dickhart, III, Transrapid International, personal communication, June 9, 1992.

[24] The Transportation Research Board estimated that more than 50 percent of the capital cost is for construction Of the track structure and guideway, 10 to 20 percent is for bringing in the power supply, 5 to 10 percent for signal and communication equipment, 10 percent for right-of-way acquisition 10 to 15 percent for design construction and management, and 10 to 20 percent for rolling stock. The Board's estimate did not explicitly include costs for stations and platforms, but did allow less than 5 percent for maintenance facilities. (Transportation Research Board, op. cit., footnote 3, table 3-3.)

the 5-year building phase.[25] Besides the jobs on the site, some secondary effects would be felt in industries that supply construction materials, e.g., concrete and steel.

Rolling stock manufacturers could get a boost from the construction of HSGT cars but the number of jobs involved is likely to be rather small. The Japanese Shinkansen, the largest HSGT system in the world, has recently been expanded and much of the rolling stock replaced. Even with this increase in procurements-288 bullet train cars purchased in 1990--the entire Japanese rolling stock industry, including parts producers, employed 14,600 workers in 1990.[26] Based on the shinkansen share of Japan's total rail car output in 1990, measured in ‘‘freight car equivalents, perhaps 3,000 people were employed in building bullet train cars that year.[27] GEC Alsthom, builder of the French TGV train, reports that a construction schedule of about 330 cars per year requires a total employment, including parts suppliers, of some 4,000 people.[28]

The figure of 300 cars per year is higher than the average number of rail cars bought in either Japan or France. France's national railroad has purchased a total of about 2,300 TGV cars (including locomotives) over the 10 years the system has been in operation.[29] Average employment created by TGV in the rolling stock and parts industries would be about 2,800 people, Considering that the total investment in the French TGV lines is about $7 billion (32 billion 1985 Francs), not including development costs,[30] TGV does not seem to be a very effective generator of manufacturing jobs. Some additional manufacturing activity is generated by the purchase of signal and communications equipment as well as the steel and concrete to build guideways. Some of the jobs in supplier industries may not be net additions, however, if construction of the HSGT system reduces the need to build other transportation infrastructure such as roads or runways.

More of the permanent jobs created by a high-speed rail system would be in operations and maintenance than in manufacturing. Backers of the Texas TGV system estimate that two legs of the system covering 461 miles, from Houston and San Antonio to Dallas-Fort Worth, would generate nearly 1,900 operations and maintenance jobs by 1998.[31] The system would require 32 train sets, which would take 3½ to 4 years to produce, and would probably employ some 1,160 to 1,350 workers over that time.[32]

DEVELOPING ADVANCED TECHNOLOGIES

HSGT systems, particularly maglev, may provide other economic benefits besides new markets and new jobs. Backers have argued that maglev, as an important customer, could spur the development of several high-tech materials that could find application in a wide range of industries. The technology driving effect of HGST may be rather moderate, however; it would mostly involve applications of existing technologies to a new environment. Certain aspects of the systems

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[25] Texas Turnpike Authority, *Texas Triangle High Speed Rail Study (Dallas, TX: The* Authority, February 1989), P. X-5.

[26] "Current State of Japan's Rolling Stock Industry," *Business Japan*, July 1991, p. 59.

[27] The Japanese Rolling Stock Manufacturers Association counts car output in terms of freight car equivalents. In these equivalent units, bullet trains made up about 18 percent of output. Assuming employment ratios are similar, only about 2,600 workers were involved in bullet train production.

[28] Pierre G. Galaud, GEC Alsthom Transportation Inc., personal communication, June 1992.

[29] GEC Alsthom Transportation, Inc., TGV promotional brochure.

[30] Ibid.

[31] Denis Doute, GEC Alsthom, telefax transmittal to OTA, Dec. 16, 1992.

[32] These estimates are based on experience in France in the manufacture of TGV rolling stock, noted above. (Information supplied by Larry Salci of Bombardier, Inc.)

(e.g., sophisticated communications and control) are also widely applicable to other fields, but it seems more likely that HSGT could be one of many user industries that support the advance of these technologies rather than a powerful driving force.

OTA found in a previous report that large-scale, multibillion dollar systems such as maglev were not likely to drive high-temperature superconductor (HTS) technology, for two reasons. First, because superconducting components are a small fraction of the costs of building a large system using these devices, the cost advantage of HTS over low temperature superconducting (LTS) equipment is likely to be small. Moreover, HTS is unproven, while the more mature LTS has proven reliable in several applications.[33]

Maglev should not be counted out as a supporter of superconducting technology, however. When the Japanese National Railways started development of maglev trains in the mid-1970s, they boldly chose a system that could use low-temperature superconducting magnets rather than one using conventional magnets, as the Germans did. Development of LTS for maglev forced solutions to handling liquid helium in a difficult environment, and this led to the development of cryogenic refrigeration equipment that has proved useful in several other very low-temperature technologies.[34] Furthermore, Japanese researchers are continuing to explore possibilities for using HTS in maglev systems. HTS would allow the substitution of safer, cheaper liquid nitrogen for the liquid helium used in LTS systems, and would involve a simpler cryogenic system. Possibly, maglev might become one of a diversified set of customers for a more mature HTS technology.

Lightweight composite materials, another critical technology, are also required in maglev vehicles. It is not clear that maglev would be central to the development of these materials; aerospace is already the leading industrial supporter of and customer for lightweight composites, and there are others as well, including sporting goods. Considering the limited numbers of cars likely to be built each year, maglev might add a rather modest increment to the R&D and the markets for these materials that are already provided by bigger industrial customers.

Construction technologies could be advanced by maglev. Building extensive elevated guideway systems would require prefabricated beams and piers built to higher tolerances than are required for road or conventional rail track construction. However, aspects of the technology might find application in bridge building, highway spans, and pretensioned concrete for transit systems.

High-speed rail systems require highly automated and precise signal, communications, and control systems. These are already standard equipment on the high-speed systems in operation in Japan, France, and elsewhere. Maglev systems can be designed to operate at still higher speeds, requiring still more highly automated and redundant vehicle tracking and control systems. Many aspects of such sophisticated systems are yet to be designed, tested, and evaluated.[35] It seems likely that these communications and control technologies will be developed in conjunction with the rail or guideway technologies involved.[36] This is an area of HSGT technology that could have synergies in related fields and other industries.

U.S. Congress, Office of Technology Assessment, *High-Temperature Superconductivity in* OTA-EM-440 (Washington, DC: U.S. Government Printing Office, 1990), p. 58.

[34] U.S. Congress, Office of Technology Assessment, Commercializing *Low-Temperature* OTA-ITE-388 (Washington, DC: U.S. Government Printing Office, 1988), p. 78.

[35] Transportation Research Board, op. cit., footnote 3, p. 40.

[36] Ibid., pp. 69-70.

EXPORT MARKET POSSIBILITIES

While both the U.S. and world markets for HSGT are fairly limited today, there is a potential in the near future for world market expansion, especially in Europe. The European Community (EC) has laid the groundwork for a 180 billion Ecu (about $250 billion) high-speed rail system to be completed in the first quarter of the next century.[37] Included in this grand scheme are new projects already underway in France, Germany, Italy, and Spain, plus additional projects in England, Belgium, Denmark and Greece. The English Channel tunnel project (the Chunnel) will be an important link in the system, providing high-speed service between London and Paris and other European destinations. Although the plan has resolved some major technical problems (e.g., standard track gauge), others remain to be ironed out. For example, because of differences in engineering, trains from different national systems cannot reach full high-speeds on each others' tracks. Also, the French TGV trains do not now have pressurized cabins, a requirement for the extensively tunneled German high-speed system.[38]

High-speed rail systems are also planned for Asian countries, including Korea and Taiwan, and for Australia. From the standpoint of geography and demographics, there may be large potential markets for HSGT in Eastern Europe, the former Soviet republics, and developing countries such as India and Brazil, but it is hard to imagine that these countries will be able to make the necessary upfront investments any time soon. Growth in these regions can only be considered a long-term prospect.

Assuming that substantial growth in HSGT systems does occur in other countries of the world, the markets those systems would offer to U.S. companies are very likely limited. The General Agreement on Tariffs and Trade (GATT) constrains countries from favoring domestic producers for many items that governments buy, but transportation systems are excluded from the GATT procurement code. Having footed the bill for developing their own HSGT systems, it is quite unlikely that European or Japanese governments would buy U.S.-made systems even if the price or technology were superior. If the GATT were amended to make HSGT procurements completely open, European and Japanese firms would still have a tremendous advantage, at least in the short term, because their technologies are proven and they have manufacturing experience.

The strategy of buying from domestic producers is also open to the U.S. and State Governments. Some of the benefits of job creation, and possibly some technology transfer, can be gained by requiring U.S. content when foreign companies build HSGT systems in this country. Texas and Florida are doing just that. Although neither system has settled on the exact percentage, domestic content in both the Texas TGV and Orlando Transrapid is expected to be well over 50 percent.

Korea is following the same strategy. The planned Korean line from Seoul to Pousan is expected to cost about $5.5 billion but is projected to generate a contract of only $390 million to the country providing the technology. The bulk of the construction and manufacturing will take place in Korea.[39] For systems installed in the United States the amount going to the foreign country could be still smaller than in the Korean case, since Korea lacks the manufacturing capability for some of the electrical equipment used in high-speed rail.[40]

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[37] Mick Hamer, ''The Second Railroad Revolution,'' New Scientist, May 23, 1992, p. 20.

[38] Ibid.

[39] Tautomo Wada, *4Nations Race to Field Asia's Fastest Passenger Train,'' *Japan Economic Journal*, Mar. 10, 1990, p. 22.

[40] Ibid.

CONVERSION POSSIBILITIES

The 1990s are the second time around for defense conversion opportunities in HSGT. Starting in the late 1960s and continuing in the 1970s, following the Vietnam War, several defense companies took part in government-led HSGT projects, including concept contracts for maglev and ‘‘air-cushion’ systems. Some of the firms invested their own funds as well as government contract money in the projects. However, when the Federal Railroad Administration (FRA) canceled its HSGT work in 1975, the major defense companies ceased most of their efforts in the field.

Today, there is renewed government support for HSGT, and several defense contractors are involved in the work. The current efforts are modest and are mostly funded by small government research contracts, as part of the National Maglev Initiative (discussed below). There has been little commitment of the companies' own funds.[41] These small-scale projects use company teams of about 5 to 10 people, mostly engineers who were already with their company and previously worked on missile aerodynamics and materials, aircraft aerodynamics, the superconducting supercollider, or the strategic defense initiative. The defense firm most involved in HSGT is Grumman Corporation. As prime contractor for one of four maglev system concepts contracts let under the National Maglev Initiative, Grumman has put together a team that includes six other engineering organizations as well as 10 researchers from its own Advanced Concepts Group. This is a small technical outfit that considers alternative nondefense applications for Grumman technologies, including such things as tilt wing business aircraft and robots for nuclear waste cleanup.

So far, neither Grumman, the leader among defense firms interested in maglev, nor any other defense companies is investing significant amounts of its own money in developing the technology. Grumman is interested enough, however, to have joined a group of companies that is trying to develop a plan for a maglev line from Washington, DC, to Baltimore.[42] If sufficient government funding is forthcoming to make such a high-risk project attractive to private firms, Grumman and other defense companies now working on small-scale research projects might well be among the participants.

To sum up, it appears that developing HSGT technology in this country and building a domestic industry could have modest but limited benefits in such things as creating good jobs, opening conversion opportunities, and driving technology advance-though it is well not to be too dismissive of the potential for technology advance, as that is notoriously hard to predict. Many of the wider societal benefits of HSGT—including reduced dependence on foreign oil, better environmental quality, and the impetus for regional economic development-could accrue to this country whether the technology used to build the systems is imported or domestically developed.

■ Government Policies to Develop HSGT

U.S. Government involvement in HSGT, maglev in particular, dates back to the late 1960s. A 1965 law established the FRA's Office of HSGT and authorized it to offer grants to companies to develop concepts and technologies for advanced HSGT systems including maglev. In total about $55 million (1992 dollars) were spent in the effort over 10 years. Industry giants such as Ford, Boeing, and Grumman participated in the program, investing their own funds in it as well as receiving government grants. In 1975, the FRA abruptly curtailed high-speed R&D funding and redirected its passenger rail resources toward

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[41] OTA interviews with research and development personnel at Grumman, Martin Marietta (Maryland and Colorado), Boeing Aerospace and Defense, Raytheon Equipment, and General Electric Corporate R&D. All these companies are participating in Federal Government contracts from the National Maglev Initiative.

[42] Garry Stix, “Air Trains,” *Scientific American,* August 1992, p. 107.

improvements to the Northeast rail corridor between Washington and Boston. The promised government aid for HSGT system development and commercialization evaporated, and the companies involved withdrew. Boeing, for example, canceled its development program and transferred the technology to Carnegie Mellon University. The Federal Government's sudden withdrawal from HSGT in the mid-1970s is a major reason companies now give for not investing their own money in maglev.

MAGLEV PROGRAMS

In 1990, Congress directed the Army Corps of Engineers, the Federal Railroad Administration and the Department of Energy to develop and jointly manage the National Maglev Initiative, a 2-year, $25-million program to assess the technical and economic feasibility of maglev and to develop systems concepts and component technologies. Four contracts ranging from about $2.5 to $8 million were let for systems concepts—ideas of what a U.S. maglev system might look like and how U.S. technology might improve upon the existing Japanese and German prototypes. Also included were 27 smaller contracts for feasibility studies and technology development. Defense contractors participated in each of the systems contracts and several of the smaller contracts.

In 1991, Congress authorized a huge increase in funding for maglev, creating a $725-million maglev development and demonstration program over 6 years as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). The National Magnetic Levitation Prototype Program calls for selection of a project that would be: 1) longer than 19 miles, to allow for full-speed operation; 2) intermodal (i.e. connect with existing air or train service); 3) located in a place with enough potential riders to allow future commercial operation; 4) able to use interstate highway rights of way, and possibly railroad rights of way; and 5) an experimental system fully capable of evaluating technical problems, including switching systems and ability to operate around curves. In awarding the contract, government officials should encourage the development of domestic manufacturers-including ones that are already in the railroad, aircraft, or automobile businesses.

The maglev prototype project could use Federal money for up to three-quarters of its cost, but would be expected to attract substantial nonfederal funding as well. No Federal money had been appropriated for the prototype program by the end of 1992.[43] A call for proposals for development of conceptual designs of the prototype awaited the feasibility reports of the National Maglev Initiative, which was expected in spring 1993. Speaking at a meeting of the High-Speed Rail/Maglev Association in February 1993, officials of the Federal Railway Administration said that preliminary results of the reports showed that maglev is feasible, and an "attractive alternative in several high density corridors, covering operating costs and varying portions of capital costs. The cost of a maglev system for the Northeast corridor would be about $22 billion all told, they said, and it could be ready by 2005.[44]

OTHER FEDERAL PROGRAMS FOR HSGT

ISTEA also included support for HSGT systems other than maglev, but at a much lower level. A total of $50 million over 5 years, including $25 million from the Highway Trust Fund, was authorized to support demonstration projects for

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[43] As noted in box 8-A, Congress has approved spending $98 million from the mass transit account of the National Highway Trust Fund for the Orlando maglev project; this is not a part of the National Magnetic Levitation Prototype Program.

[44] Statements of Robert Krick, Deputy Associate Administrator for Technology Development for the National Maglev Initiative, Federal Railroad Administration U.S. Department of Transportation% "NMI Status Report," statement at the 1993 High Speed Rail/Maglev Forum, Feb. 25, 1993; Gene Koprowski, "Magnetic Levitation: Reality in 2005 for Just $22 Billion!" New *Technology Week, Mar.* 1, 1993, citing statements by Krick and Arrigo Mongini, Deputy Associate Administrator for Railroad Services, Federal Railroad Administration U.S. Department of Transportation.

HSGT technologies of any kind (including steel wheel on rail) for use in a system that is actually in operation or under construction. Another $25 million (from general funds) was authorized for R&D of all kinds of HSGT technologies; the law specified that the government could provide 80 percent of the costs in R&D partnerships with industry on HSGT technologies. ISTEA also required a report from the Department of Transportation by June 1995 on prospects for various forms of HSGT, including: 1) an economic and financial analysis, including projections of both costs and potential markets; 2) a technical assessment, including both environmental and safety issues and unresolved technical issues; and 3) recommendations for model legislation for State and local governments to pave the way for construction of HSGT systems.

STATE EFFORTS TO PROMOTE HSGT

Many State Governments actively promoted the development of HSGT, starting with feasibility studies and technology assessments of high-speed rail. Several, including Florida, Ohio, and Pennsylvania, have gone beyond feasibility studies to pursue environmental assessments and engineering studies. Funding for full-scale development remains a problem. In 1987, Ohio voters rejected a measure that would have created a special sales tax to support HSGT development and construction, Florida planned to help finance construction of a HSGT system by granting the builders land around proposed stations, which the builders could then sell; however, a sharp drop in the Florida real estate market killed the scheme.

In Texas, the State legislature that awarded the franchise for the TGV project stipulated that no State money could ever be appropriated for it. However, backers are trying for permission to use tax-free bonds to finance about $2 billion of the construction costs (see box 8-A). This option is also strongly favored by backers of HSGT systems elsewhere in the United States. Under the U.S. Tax Code, States or localities can issue tax-free bonds on behalf of private companies to build projects that result in a public good. Because no Federal or State income tax is collected on the interest paid to the bondholder, individual investors are willing to accept a lower rate of interest than they would accept for similarly risky taxable bonds. Since not all States collect income tax, and those that do charge rates much lower than the Federal income tax, most of the advantage that tax-free bondholders receive is at the expense of the Federal Treasury. It is estimated that every $1 billion in tax-free bonds costs the Federal Treasury $33 to $50 million; thus the cost to the government of the planned $2 billion bond issue by the Texas TGV could be $60 to $100 million.[45]

Tax-free industrial development bonds (IDBs) have funded the construction of water and sewage treatment plants, low-income housing, and, in the past, projects that simply generate jobs. Because most of the cost is borne by the Federal Government, and because security for the bonds is usually no more than the income and assets of the firm receiving the bond, local governments have little reason for restraint in issuing IDBs. In 1986, Congress limited the scope of IDBs, setting caps on how much money each State can issue in IDBs every year. Certain projects were excluded from the caps-including airports but not railroads. Both the Orlando and Texas high-speed rail developers are urging congressional action to amend the law so as to treat railroads like airports.

INTRACITY MASS TRANSIT

Mass transit, particularly rail transit, within cities has also been proposed as meeting public needs while also serving as a candidate for defense conversion. The potentials for reducing emission of greenhouse gases from cars, improving urban air quality, reducing traffic congestion,

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[45] Matthew R. Marlin, ‘ ‘Industrial Development Bonds at 50: A Golden Anniversary Review, “ *Economic DevelopmentReview, vol. I, No. 4,* September 1987, p.397.

and cutting dependence on foreign oil are public benefits claimed for mass transit. As for the conversion potential, the idea that defense aerospace companies might convert to rail transit car production is by no means new. The 1970 Surface Transportation Act[46] specifically authorized the Federal Transit Administration (then the Urban Mass Transit Administration) to "encourage industries adversely affected by reductions in Federal Government spending on space, military and other Federal Projects to compete for contracts. '[47]

Defense contractors have some advantages in the mass transit business. First, they know how to compete for government contracts. While bidding for mass transit means responding to calls from local governments, not the Department of Defense, there is at least some similarity in marketing methods. Second, some of the manufacturing skills a defense a.ir-framer must have are also required in building a rail car. In both cases, manufacture means integrating components supplied by subcontractors. Like the airframe integrator, the prime contractor for rail cars usually builds the structural frame and the shell, but subcontractors generally furnish the powertrain components, the electronic controls, and the other major systems. Fabrication is completed by skilled craftsmen. In neither case are mass production techniques employed.

On the other hand, there are major differences between aircraft and rail car manufacture. Some are technical; for example, aircraft are made of riveted aluminum, lightweight steel alloys, and composites, while subway car bodies are generally constructed of welded stainless steel or welded aluminum. More important are differences in approach to cost. In military orders, the paramount consideration is performance; costs, while important, are secondary. With rail cars, as in any civilian market, cost is a primary issue. Furthermore, manufacturers of aircraft are used to operating at a very large scale in programs worth billions of dollars. The market for rail cars is limited and diffuse, with many competitors battling for small contracts that follow no predictable timetable.

Some observers believe that an infusion of new technologies from aerospace fro-for example, in advanced materials and microelectronic controls-could improve mass transit manufacture. The negative factors are stronger, however. As noted, a most important factor is the small size and unpredictable nature of the market for rail cars. The absence of uniform standards for transit cars makes it hard to achieve economies of scale. Past experience does not provide much evidence for the practicality of conversion. The 1970s ventures by defense companies into mass transit car production were not a total fiasco; some were spectacular failures, financially and technically, but a few eventually achieved modest technical success. Boeing-Vertol, after a rocky start with an order for subway cars in Boston, later improved enough that cars delivered to Chicago and San Francisco gave years of reliable service. Allied Signal developed electronic "chopper" switches so successfully that at one point in the 1970s it supplied electronic controls for every U.S. and Canadian light rail program.[48]

None of these ventures lasted, not even those that achieved technological success. Boeing closed out its light rail car operation in the early 1980s, and in 1988 Allied Signal sold its transit control business to the Swedish-Swiss firm Asea Brown Boveri. Shifting government policy on mass transit was responsible in part, but probably a greater factor was a defense buildup that offered

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[46] Public Law 91-453.

[47] Public Law 91-453, sec. 10.

[48] For an account of defense companies' ventures into mass transit manufacture, see U.S. Congress, Office of Technology Assessment, *After the Cold War: Living With Lower Defense Spending*, OTA-ITE-524 (Washington, DC: U.S. Government Printing Office, February 1992), pp. 206-210.

far more rewards than any available in transit. Difficulties also stemmed from the different demands on managers in commercial business—especially in cost control, attention to reliability, and marketing ability.

OTA's analysis finds that the market for mass transit rail cars is generally less than $750 million per year, is highly variable, and is divided among many firms that are, with one exception, foreign-owned. Possibly, the Federal Government might take actions to make the market more hospitable by encouraging standardization of mass transit cars, supporting larger numbers of purchases, and working with local transit authorities to create a more orderly pattern of purchases. Even so, the market would not approach the size of declines in defense aerospace purchases, and foreign firms still have a big lead over novice U.S. fins. It is not clear that defense firms are particularly well situated for or interested in entering the mass transit market. While there may be sound arguments for more government support of mass transit than already exists, on grounds of public benefits to energy independence and protection of the environment, the opportunities for conversion and for growth of a sophisticated, dynamic domestic industry appear to be limited.

The Products

The mass transit rail car market comprises three basic categories: rapid rail transit (sometimes called heavy rail or metro rail), light rail vehicles (contemporary descendant of the trolley car), and commuter rail. Because each of these markets is quite small, most builders are involved in all three.

Rapid Rail Transit (RRT)--These are the cars typically used in subway and elevated transit systems. They are self-propelled and electric-powered, either from a third rail or overhead wires, and they can be strung together in trains of up to 10 or more cars. Only 12 RRT systems are in operation in the United States, but RRT comprised 66 percent of all transit cars delivered between 1981 and 1991 (table 8-l). RRT cars are typically priced from $800,000 to $1.5 million, depending on size, technological sophistication, and the size of the order.

Table 8-l-Total New Transit Cars Delivered, 1981-91

Type	Number	Percent of total
Rapid transit . . . . ,.	3,781	66%
Light rail	696	12
Commuter rail	1,281	22
Unspecified.	8	0
Total	5,766	100%

SOURCE: "Passenger Car Market at a Glance," *Railway Age,* January annual, 1982-92.

The RRT market is dominated by New York City's Transit Authority (NYCTA), the Nation's largest system; it operates 59 percent of all RRT rolling stock and accounted for 45 percent of new RRT of purchases in the last decade (table 8-2). Other major buyers of RRT cars are the Chicago, San Francisco, Boston, and Philadelphia systems, plus newer systems in Washington and Atlanta. Los Angeles, Houston, and Honolulu are all planning to begin operating RRT systems by the year 2000, but even in combination these systems will not add significantly to the total demand for rail cars. None of the planned systems has contracted for more than 150 cars. Altogether, RRT sales averaged about 350 a year between 1981 and 1991.

Light Rail Transit (LRT)--These cars, the offspring of the traditional trolley car, are simpler and less expensive than those used in RRT systems, and are designed to serve areas with lower population density. LRTs can be connected into trains of two or three cars, are often articulated to accommodate tight turns, and are generally powered by overhead wires. The guideways can be at street level, elevated, or underground. There are 17 light rail systems in operation in the United States, 7 of which opened between 1981 and 1991, but only 12 percent of transit cars delivered during the decade were of this type.

Table 8-2—U.S. Rapid Rail Car Fleets

Transit operator	Fleet size	Percent of total	Average age	Percent over 25 years old
New York-MTA	6,089	59.0%	18.-I	37.7%
Chicago	1,214	11.8	13.6	23.0
Washington	664	6.4	8.7	0,0
San Francisco	579	5.6	12.9	0.0
Boston	404	3.9	14.6	20.3
Philadelphia	378	3.7	23.3	66.9
New York-PATH	342	3.3	17.8	0.0
Atlanta	238	2.3	6.9	0.0
Miami	136	1.3	8.0	0.0
New Jersey-PATCO	121	1.2	17.4	0.0
Baltimore	100	1.0	5.4	0.0
Cleveland	60	0.6	7.0	0.0
Total	10,325	100.0%	18.1	28.2%

KEY: MTA=Metropolitan Transportation Authority; PATH=Port Authority Trans-Hudson; PATCO=Port Authority Transit Corporation (Pennsylvania-New Jersey),

SOURCE: Department of Transportation, Urban Mass Transportation Administration, Washington, DC, *Data Tables for the 1990 Section 15 Report Year,* December 1991.

Small order sizes make light rail cars a particularly difficult segment for manufacturers.

Commuter Rail Transit--These systems, designed to bring large numbers of commuters into downtown from more distant suburbs, operate between more widely spaced stations on fixed schedules. Commuter rail cars may be pulled by locomotive or may be self-propelled. They represent a growing sector of the market, accounting for 22 percent of the transit cars delivered from 1981 to 1991. In 1990, 13 systems were in operation with at least two more scheduled to begin operation in the 1990s.

The U.S. Market

Deliveries of transit cars surged in the 1980s (table 8-1), largely due to increased purchases by New York City and the demand created by new or expanding systems in Washington, Atlanta, San Diego, and Sacramento. The average for the period 1981-91 was 525 cars of all types per year. Even in this time of relative plenty there were great variations in deliveries from year to year. In 1986, the best year, 1,152 cars were delivered, while only 148 cars were delivered in the worst year, 1990.[49] Among some car types the variation was greater; 854 RRTs were delivered in 1986 compared with only 6 in 1991.

New York was by far the largest purchaser during the decade, buying some 1,713 of the total 5,766 new cars delivered, and dominated the rapid rail market (45 percent of all purchases). Only one other system, Chicago's elevated transit, purchased more than 200 cars, and two others--San Francisco and Washington-bought more than 100 cars from 1981 to 1991.

Although the 1991 Intermodal Surface Transportation Efficiency Act authorized a large infusion of new Federal money into mass transit, industry analysts expect that the next several years will not generate as much demand for new rolling stock as the 1980s brought. A backlog of 914 unfilled car orders existed at the end of 1991; orders for 761 cars were expected in 1992, and between 820 and 1,640 more from 1993 to 1997. Orders of more than 175 commuter rail cars were projected for the 5-year period, but only three cities were expected to order more than 150 RRT

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[49] All data on rail car sales are from "Passenger Car Market at a Glance," *Railway Age,* January annual, 1982-92,

cars. In light rail, only Boston was expected to order as many as 100 cars and no other order was expected to exceed 50.[50]

Additional Federal Government funding might increase demand but probably not by very much. Many systems are already operating new rolling stock. New York took delivery on 2,350 new and remanufactured cars in the 1980s and its average fleet age is down to 18.1 years; the average life expectancy for RRT cars is 40 years.[51] New demand might arise from construction of new systems and the expansion of existing systems but, as happened with projects started in the 1970s (e.g., Atlanta, Washington), car purchases would not get underway until the next decade. Prospective locations for large new systems are limited. Dallas, Houston and Honolulu are building RRT systems, but there are few other locations that would be likely to require orders of more than 100 cars.

Los Angeles is one place where large-scale growth in the rail car purchases can be expected. Because of its air pollution and traffic congestion problems, Los Angeles has committed to spend $185 billion between 1990 and 2020 on transit improvements. A major element will be rail. Two light rail lines were operating in 1992; one section of a short RRT opened in early 1993, to be completed later in the decade; and other commuter and light rail developments are also planned. Los Angeles expects to procure a total 600 cars including RRT, LRT, and commuter rail cars over the 30 years.[52] Of these 600, 250 are either currently under requests for proposals or have already been contracted for. Altogether, even with its huge investment in mass transit, Los Angeles will probably add only about 20 cars a year, on average, to the total U.S. demand.

The Competitive Environment

The U.S. rail car manufacturing market is nothing if not crowded (table 8-3). More than 25 firms supplied cars to U.S. transit systems in the 1980s. Until the entrance of Morrison Knudsen in 1991, no rail transit car had been manufactured by a U.S. firm since 1984, when Boeing-Vertol delivered its last car to San Francisco Municipal Railway. The Budd company, the last major U.S. rail car builder, was bought by a German company in the late 1970s and delivered the last car under the Budd nameplate in 1984. Budd continued U.S. operations under the name Transit America until 1987 when its backlog and facilities were purchased by Bombardier of Canada.

The large number of companies competing for orders in the 1980s led to variation in deliveries by individual firms even more drastic than those seen at the market level. Only Kawasaki delivered cars in every year from 1981 to 1991. Bombardier, which held 23 percent of the total market in the period, made 948 of its 1,366 deliveries in just 2 years; 825 of these cars were bought under a single contract. Even its position as market leader does not give Bombardier a consistent ability to win major contracts. Budd controlled 21 percent of the 1981-91 market even though it disappeared as a company in 1987.[53] Kawasaki delivered 970 cars, 17 percent of the market.[54] Some firms

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[50] Ibid.

[51] U.S. Department of Transportation, Federal Transit Administration, *Data Tables the 1990 Section 15 Report Year* (Washington, DC: U.S. Department of Transportation, December 1991), table 2.17.

[52] The contract for the Los Angeles Green Line cars was originally awarded to Sumitomo of Japan, the contractor for the city's Blue Line cars. Sumitomo was selected over Morrison Knudsen of the United States despite the latter's lower bid. Los Angeles transit operators felt that Morrison Knudsen's engineering skills were not thoroughly tested, casting doubt on their ability to deliver high-quality cars on schedule. Morrison Knudsen launched a campaign to reopen the bid. Their campaign was framed in terms of U.S. jobs lost and Japanese economic domination. As public sentiment against Sumitomo increased, the transit authority canceled the contract. Sumitomo was later awarded a smaller contract.

[53] Includes sales made by Transit America in 1985 and 1986.

[54] Includes all sales where the trading company Nissho Iwai is listed as the prime contractor.

Table 8-3--U.S. Rail Transit Car Deliveries, 1981-91

	1981-85		1986-91		Total 1981-91	
Country of origin	Number	% of total	Number	% of total	Number	% of total
United States	1,004	40%	316	10%	1,320	23%
Canada	301	12	1,320	40	1,621	28
Japan	863	34	674	21	1,537	27
Europe	335	13	953	29	1,299	22
Total	2,503	100	3,263	100	5,766	100

SOURCE: "Passenger Car Market at a Glance," *Railway Age,* January annual, 1982-92.

supplied cars only to a single system, often under a single order. Hitachi of Japan supplied 90 cars to Atlanta from 1984 to 1987. Westinghouse Amrail, a consortium of European companies, provided 419 RRT cars to New York. Breda of Italy had two customers, supplying 356 cars to Washington after selling 59 to Cleveland in the early 1980s. The remaining firms delivered fewer than 250 cars each and did not make deliveries in more than 4 of the 11 years.

Some Japanese manufacturers have arrangements with trading companies that allow them an extra measure of flexibility in this highly unstable market. While some trading companies such as Nissho Iwai have longstanding relationships with a single builder (Kawasaki), others subcontract with various builders and may even divide the work from a single contract among builders. This arrangement allows Japanese firms to bid on contracts that would otherwise be beyond their capacity. In contrast, U.S. firms--those still operating in the 1970s and early 1980s—were either fully loaded with work or had no contracts at all.

Only one U.S. firm has entered the transit industry in the last 15 years-Morrison Knudsen. The company has a strong tradition of rail work, including locomotive and freight car rebuilding. It moved into the transit market slowly, first rebuilding older cars and only then designing and building new cars. Its investment has been at a cautious pace. It does not yet have a plant to build car shells, instead importing them from overseas. Even with this cautious incremental strategy the company has invested around $70 million in plant and equipment to build transit cars. Morrison Knudsen had advantages that future U.S. entrants are unlikely to have, that is, rail experience and large rebuilding projects that gave its people some learning experience before entering full-scale engineering of a new car. Even with these advantages-and even with the further benefit of preference by transit authorities for domestic builders, as discussed below—the company may not be a viable long-term competitor in the new rail car market.

Preference for National and Local Manufacturers

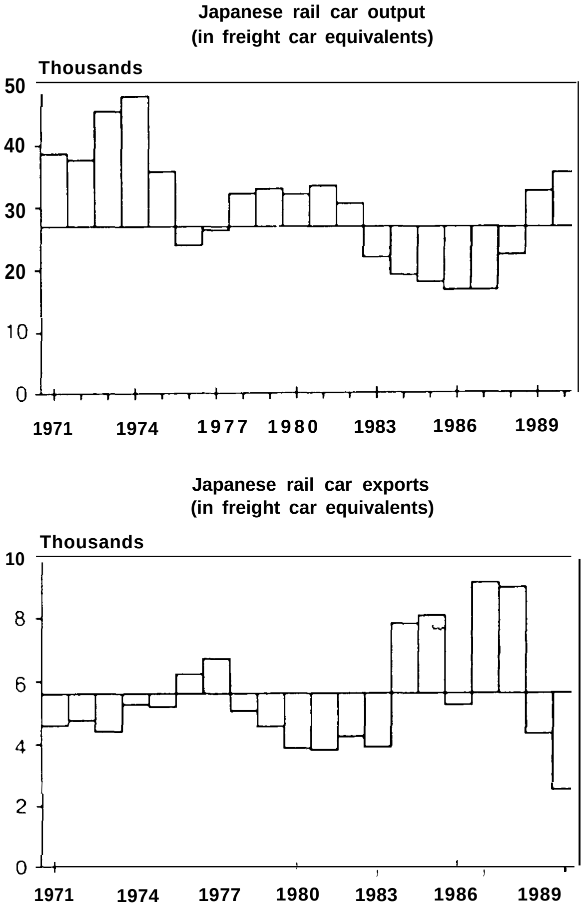
Most countries with a transit car manufacturing industry provide some form of protection for domestic producers. Under GATT, the international agreement governing trade among most of the world's nations, many areas of government procurement cannot offer explicit preference for domestic fins. However, transportation remains a so-called ‘‘excluded’ sector in the GATT procurement code; governments may use various devices (such as price preferences) to favor domestic firms. Informal barriers, such as failure to provide information to foreign bidders about technical specifications and contract procedures (“lack of transparency’ can be an even stronger form of protection, as they are in Japan and Europe.

Besides their arrangements for work sharing and collaboration, the car builders in Japan benefit from a large, protected domestic market. The benefit shows up in sales and export figures for rail cars made in Japan from 1971 to 1990 (figure 8-l). Exports are a small share of total output. But it is striking that, in nearly every year when total output (comprising mostly domestic sales) fell below average, exports rose above average. Conversely, when total sales were above average, exports fell below average. This record suggests that the Japanese producers were able to use exports to the United States and other countries to sop up some excess capacity during slack times in domestic demand.

The strategy of using exports to compensate for lower domestic demand rests partly on a predictable procurement system. In Japan, rail car producers get enough warning of planned lower purchases that they can bid on foreign contracts to smooth out production. Interestingly, despite the apparent coordination in the Japanese market, the Japanese Rolling Stock Manufacturers Association pleads for more cooperation among firms and railway operators.[55]

The United States has its own form of protection--one that is more explicit but probably easier to evade than informal barriers. The idea that government spending should benefit American firms underlies a series of Buy America requirements in the Federal Acquisition Regulations.[56] For the most part, Federal Buy America provisions apply only to goods purchased directly by the Federal Government.[57] However, under the Surface Transportation Act of 1978, the Federal Transit Administration (then the Urban Mass Transit Administration) was authorized to require that rolling stock purchases made fully or in part with the Agency's grants have Buy America preferences.[58] Firms not qualifying as U.S. firms must bid at least 25 percent lower than competing "domestic' bids to win a contract. However, in order to be considered a U.S. firm, a manufacturer need only have 60 percent of the content of the car produced in the United States and complete final assembly in the United States. In practice, Buy

Figure 8-l-Japanese Rail Car Industry



SOURCE: "Passenger Car Market at a Glance," *Railway Age,* January annual, 1982-92.

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[55] Japanese Rolling Stock Manufacturers Association, *FY 1990 Rolling Stock Industry Annual Report* (Japan: The Association, 1991) (in Japanese).

[56] For a brief discussion of Buy America provisions and Federal Government procurement, see U.S. Congress, Office of Technology Assessment, *Competing Economies,* ITE-OTA-498 (Washington, DC: U.S. Government Printing Office, 1991), ch. 4.

[57] Many States have their own Buy America requirements for their procurements.

[58] Public Law 95-509, Section 402, 1978.

America as applied to rail is not a price preference but rather a content requirement. All contracts awarded in the 1980s that were required to meet Buy America did so by having sufficient U.S. content. By leaving the market open to foreign carbuilders, the requirement promotes competition while at the same time attempting to assure that companies manufacturing in the United States capture at least 60 percent of the value of the car.

In the Uruguay round of negotiations over GATT, some U.S. trading partners proposed a new procurement code, in which transportation could no longer be an excluded sector, and therefore able to offer domestic industries national preference. U.S. negotiators were unwilling to accept this change in the code without firm assurance that European and Japanese informal barriers to the purchase of U.S.-manufactured transit cars would be removed if transportation were no longer an excluded sector.[59]

State or Local Content Requirements

In some cases where transit authorities have not received any Federal funding for their rolling stock purchases, the logic of Buy America has been extended to the State or local level. Such State or local content requirements are not allowable if Federal funds are used.[60] While few if any rail cars were purchased in the 1970s without Federal funding, only about 55 percent of those built in the 1980s used Federal money .61

Many of the largest transit agencies self-financed in the 1980s. In its enormous State-funded 1981 order, the New York City Transit Authority considered New York content as one factor in the selection process but did not require State offsets *per se*. State content was easy to include because many suppliers are located in New York. In its 1990 order for 173 commuter rail cars, Chicago required final assembly in the five-county area surrounding the city. This forced Chicago's contractor, Morrison Knudsen, to set up an entirely new facility in the area. The benefit to Chicago area workers may be temporary. While Morrison Knudsen is hoping to continue operation of the Chicago facility by converting it to a rail car body plant (currently the company imports car bodies from Japan and Switzerland), officials admit that the long-term viability of the facility will hinge on receiving enough new orders to justify the company's construction of its own car bodies.[62] Morrison Knudsen is also building a facility in California as part of its contract for the so-called 'California' commuter car.[63] All of this investment in excess capacity has fueled speculation that Morrison Knudsen will not be able to survive in the transit car market.[64]

Rising demands for local content are seen by some in the industry as a threat to the fragile domestic supplier base. This applies to components suppliers at least as much as to final integrators. As with many products involving large-scale systems integration, a sizable share of the value of a rail car resides with component

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[59] U.S. Trade Representative official, personal communication, June 1992.

[60] Urban Mass Transit Administration "Third Party Contracting Guidelines, " circular UMTA C 422D.1B, May 8, 1988, paragraph 4, subparagraph b.

[61] Based on *Railway* Age market data and telephone interviews witb transit operators. One reason for the increase in local financing was that Federal Government support declined in the 1980s, both in number of grants given and the share of the purchase covered. Also, many transit authorities believed that they could get more car for less money without Federal assistance that imposed procurement regulations covering such things as minority firm participation labor-surplus area firm participation and sealed-bid selection.

[62] Morrison Knudsen claims t. have capacity in a New York facility to build 900 cars a year, far more than the number likely to be built there currently. Therefore, it is unlikely that the company wouid have built a facility in Chicago if not for the contract requirement. Information provided by Morrison Knudsen company official, July 1992.

[63] Don Phillips, "Getting the U.S. Back on Track,'' *Washington Post, May 24, 1992,* p. H-1.

[64] Richard L. Stern and Reed Abelson, ''The Imperial Agees," *Forbes,* June *8, 1992,* p.88.

suppliers. Los Angeles Transit Authority estimates that about 45 percent of the price of the car is components or work done by component makers or suppliers.

Because of Buy America national preferences, U.S. parts suppliers have a considerably better market position than U.S. carmakers. However, the growing use of all-local financing has allowed States and localities to both circumvent Buy America requirements and require State or local content. Because the market for transit car components is already quite small any loss of sales can have a significant impact. If foreign builders are not required to meet Buy America content requirements, U.S. suppliers lose sales. More subtly, local offsets can increase firm costs by forcing them to set up gypsy manufacturing facilities in the State or locality offering the contract, thereby limiting what few economies of scale or scope might exist.

American Manufacture of Rail Cars for Mass Transit

The focus of this chapter is on the jobs, conversion opportunities, and technology advances that new transportation systems might offer. Through this lens, mass transit does not look like a big winner.

If manufacture of mass transit cars experienced a revival in the United States, it probably would not generate many jobs. The issue is relevant to defense conversion, since transit car production is often mentioned as a candidate industry to absorb some of the job losses in the defense industry .65 Most large defense contractors are extremely wary of getting into the transit business because of the well-known failures some defense companies suffered in the 1970s in their transit ventures. One of these efforts--Boeing-Vertol's production of light rail cars in the 1970s and early 1980s—was modestly successful. Even so, it yielded fewer than 500 jobs, compared with more than 5,000 jobs lost at Vertol in the post-Vietnam War build-down.[66] A Kawasaki-Nissho Iwai plant in Yonkers, New York, which builds car bodies and does final assembly, would employ only about 300 people at its full output of about 120 cars per year.[67]

Because subcontracted components make up as much as 50 to 60 percent of a car's value, the jobs generated by parts suppliers are at least as important as those in the integrator's plants. Buy America requires foreign producers to generate 60 percent of the car's value in the United States, and in most cases transit authorities that do not use Federal money impose similar requirements; therefore, most of the extra jobs in a domestic industry would be at the final integrator level. Assuming that 550 cars (the yearly average of purchases in the 1980s) were built entirely in the United States, transit car manufacture might create as many as 1,400 new jobs.

As matters stand, there is not much prospect of growth in the U.S. market. Replacement sales are occurring at a steady rate and few systems expect large increases in demand for cars. New systems could and perhaps should be built. If government policy were to support mass transit more strongly, they might be. However, most recently built systems have been small. Currently, only Los Angeles seems likely to be a large new source of future demand and only over the long term. The addition of some 20 cars a year from Los Angeles

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6s Northrop, principal contractor for the B-2 bomber, faces a large loss of business when the much truncated run of the B-2 ends (the program was cut to *20* planes from what was once envisioned as several hundred). Reportedly, Northrop approached the Japanese firm Sumitomo as a possible subcontractor for manufacturing transit vehicles for Los Angeles. In late 1992, however, company officials said prospects for the deal were dead.

66 Boeing-Vertol official, personal communication, June 1992. Total employment in helicopter building at Vertol in Philadelphia dropped from about 12,000 at the peak of war production to 6,700 in the later 1970s.

67 Union Rail Car, Yonkers, NY, promotional literature.

orders over 30 years does not make a big difference in the U.S. market, or in job prospects.

The assumption that domestic manufacturers could displace foreign producers is itself an unlikely one. The U.S. transit car market is crowded with fierce competitors, most of whom are foreign. It also seems unlikely that U.S. companies entering the field could profit much from exports. It would be hard to best experienced foreign competitors in their own markets, where most have the added advantage of protection via both formal and informal barriers.

Another issue is the place of advanced technology in mass transit. Could new U.S. firms enter the market on the basis of new technology? Or could technologies developed for transit cars be more broadly applied in other sectors? Any answer has to be rather speculative. U.S. transit operators are typically very conservative about employing new technologies. Difficulties in implementing new technologies in the early 1970s that led to costly delays and embarrassment continue to influence decisions on employing new and unproven technologies. Reliability, longevity, and safety are the key ingredients operators look for in new rail cars. Moreover, transit budgets are very limited. Operators want assurance that extra dollars spend on new technologies will lead directly and obviously to lower operating costs or greater ridership.

On the other hand, some foreign transit systems do have advanced technical capabilities that operators there were willing to pay for. Completely driverless systems, microelectronic train control using 'fuzzy logic' algorithms, and other technologies not yet used in the United States have been installed in foreign transit systems. Some of these technologies are broadly applicable; a mass transit market for them here might provide support for their further development and spillover to other fields. Still, U.S. firms wishing to compete on the basis of technology would have to leapfrog the substantial advantage held by European and Japanese firms that are already in the business of supplying high-tech components and services, and that have done more R&D in mass transit over the last 25 years than U.S. firms.

The potential for a contribution from U.S. high technology firms cannot be written off. Some may be able to make inroads in the transit business at the component or subsystems level. Although the U.S. markets would likely be small, there might be possibilities for export. In its request for proposals to build 87 light rail vehicles, Los Angeles tried to encourage U.S. defense firms to investigate the transit component market. It included a requirement that bidders team with a high-tech firm to apply a new technology in two prototype advanced vehicles, and then evaluate the results.[68] The first 40 cars built under the contract would use more conventional technologies, but the second 45 would incorporate the advanced technology if it were found useful and cost effective. The goal of the Los Angeles program is not to create new car building companies but to encourage the formation of a new components industry that all of the world's manufacturers could draw on.

Mass transit may be judged an important element in meeting environmental and infrastructure challenges; this report does not assess transit systems from that point of view. The possibilities for new job creation in a domestic mass transit car industry are probably still less than the limited potential offered by highspeed intercity ground transportation systems. As for technology opportunities, there may be some scope for selling advanced components for transit systems in the world market. So far, Japanese and European components suppliers have the advantage of working with domestic car manufacturers, and are ahead of potential American competitors.

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[68] Travis Montgomery, economic development specialist, Los Angles County Transportation Commission, personal communication, July 1992.