PORTRAIT OF A WHISTLE-BLOWER ■ HIGH-SPEED RAIL FOR U.S.?

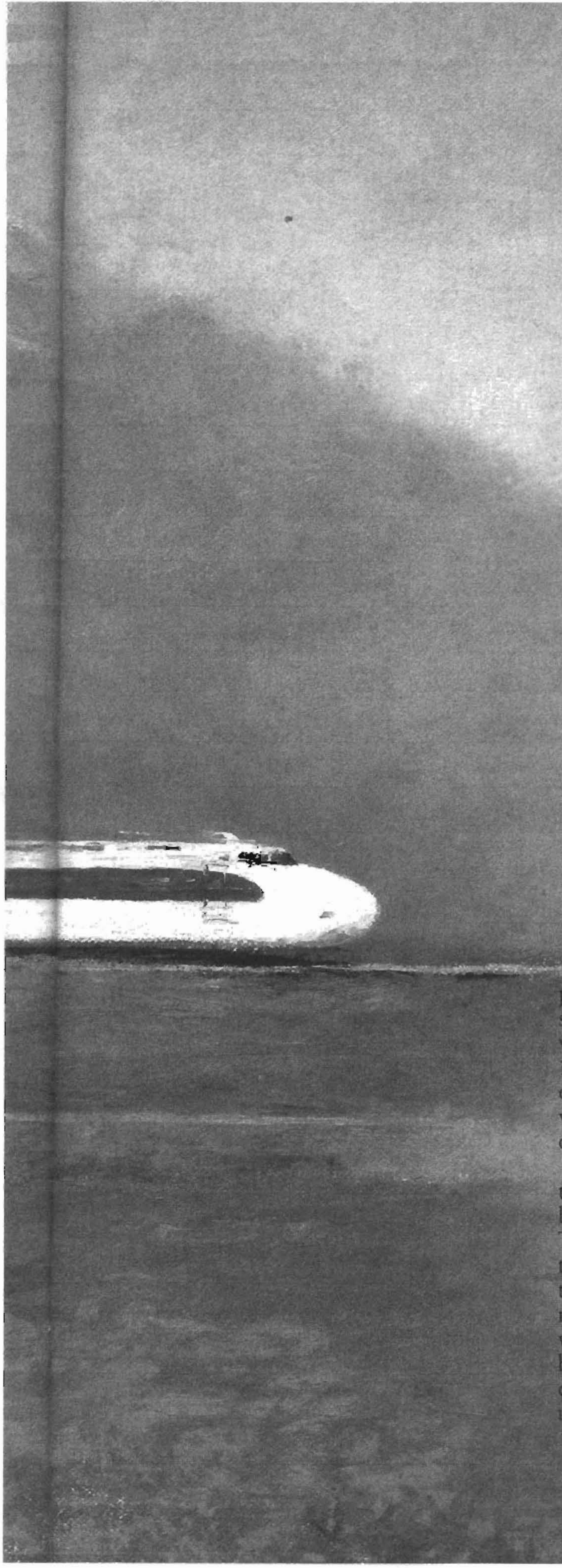
THE COMPLEX ETHICS OF EXPORTS

Technology Review

EDITED AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY APRIL 1986 $3.00

IDEAS TO PRODUCTS

WHY JAPANESE ENGINEERS GET THERE FASTER



High-Speed Rail

The technology is waiting,
the vision seductive.
But balancing costs and benefits,
tangible and intangible,
is controversial.

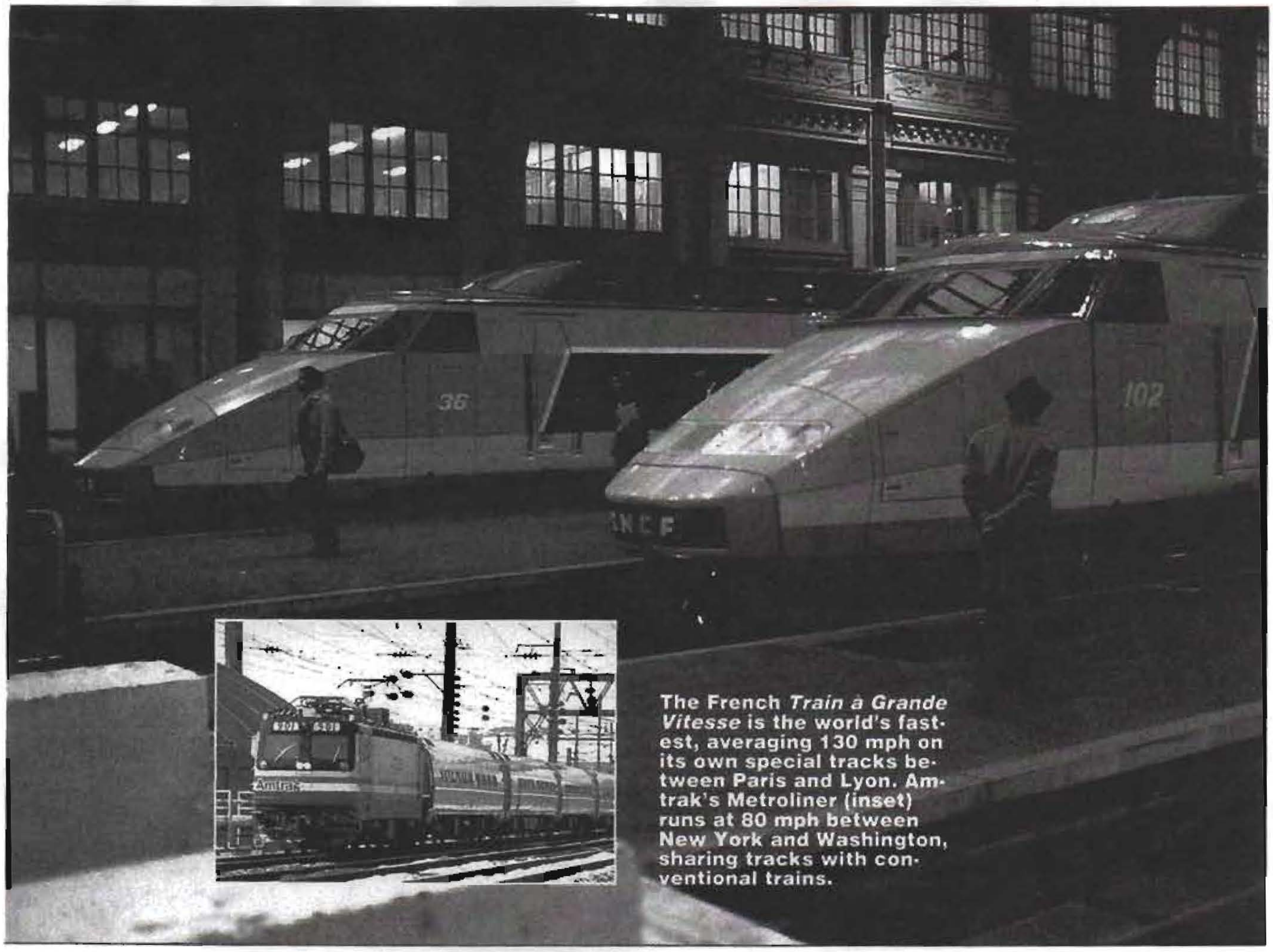
BY LOUIS S. THOMPSON

Is there a future for high-speed intercity rail transportation in the United States?

Skeptics abound, calling attention to the plight of Amtrak and other conventional rail passenger services, which exist in the United States only where heavily subsidized. But within the past 5 to 10 years our country has seen a dramatic resurgence of interest in building high-speed rail systems, on which trains operate at 120 miles per hour or more over significant sections of their routes.

Since entering service in 1964, Japan's first electric-powered *Shinkansen*, which averages slightly better than 100 mph over its 600-mile route between Tokyo, Osaka, and Hakata, has completed more than 2 billion passenger trips without a single fatality—proving that high-speed rail is not only technically feasible and safe but also marketable, at least when the population density and the demand are high. The British High-Speed Train has shown that diesel-powered equipment can operate on tracks also used for conventional service. Finally, the French

ILLUSTRATION: PAUL MOCK



The French *Train à Grande Vitesse* is the world's fastest, averaging 130 mph on its own special tracks between Paris and Lyon. Amtrak's Metroliner (inset) runs at 80 mph between New York and Washington, sharing tracks with conventional trains.

Train à Grande Vitesse (*TGV*), which averages 130 mph between Paris and Lyon, has successfully tested two engineering innovations: unprecedented steep gradients and speeds of up to 170 mph—nearly 40 percent faster than any previous train.

The United States entered the high-speed rail sweepstakes in 1976 by upgrading the Metroliner in the Northeast Corridor between Washington and Boston. The fastest service now operates at 120 mph over about half of the distance between Washington and New York, and the top speed will rise to 125 mph within about a year as improvements are completed. Because of station stops and some unavoidable speed restrictions, the average Washington-to-New York speed is just under 80 mph. (This compares with an average of just over 50 mph between New York and Boston, where diesel power and circuitous track, much of it shared with heavy commuter service, reduce speed.)

As train speeds have increased between Washington and New York, patronage has slowly improved—even from a base inflated by a gasoline shortage and despite airline deregulation that has encouraged vigorous competition in price and service. This success, together with that elsewhere in the world—indeed, there is no example of a failed high-speed rail service—has resulted in several proposals for new U.S. routes from groups of potential high-speed rail investors, suppliers, and operators that are listed in the chart on page 40. And the likely roles of various parts of the public sector are becoming more clearly defined.

The Key Variables in Planning

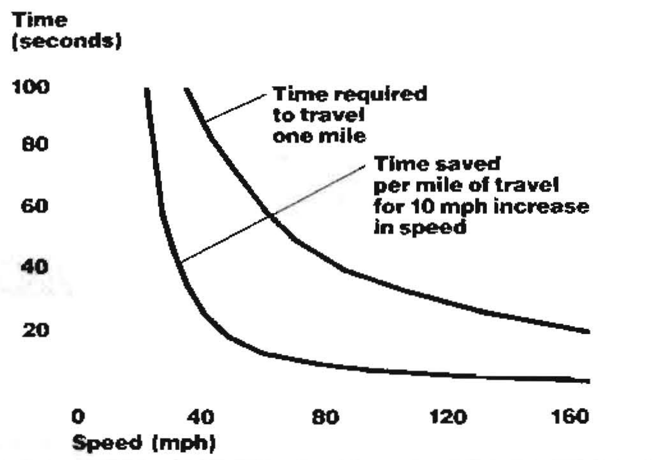
Unfortunately, something about a high-speed railroad leads people to focus on the parts instead of the whole. One reason is that users see only the stations and the equipment; they do not appreciate the extent or cost of the civil engineering facilities—

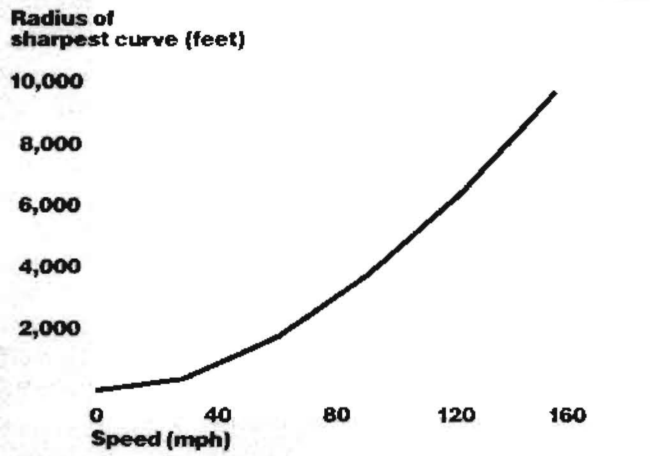
LOUIS S. THOMPSON is associate administrator for passenger and freight services in the Federal Railroad Administration. He studied engineering at M.I.T. (1963) and business administration at Harvard (1965), and prior to taking his present post was an economic and engineering consultant and an official in various capacities of the U.S. Department of Transportation. The opinions expressed here are those of the author and do not necessarily represent official views of the Department of Transportation.

PHOTOS: ERNEST H. ROBL, LOUIS S. THOMPSON

Top: For trains that are already moving fast, increases in speed yield smaller and smaller reductions in travel time. This is not an argument against high-speed rail. Rather, it is an argument for high-speed lines with few intermediate stops.

Bottom: The amount of centrifugal force that passengers can tolerate limits the sharpness of curves that can be built into any rail line. And as the speed for which a line is designed increases, this limitation becomes markedly more severe.





the roadbed, track, and bridges. Another reason is that many people, taken up with the romance of railroading, see a modern railroad in the image of the past.

In reality, a modern high-speed railroad is a carefully designed, highly integrated system of many complex components. Hard experience has taught us that components from old systems can seldom be used efficiently with new systems. The Northeast Corridor track—the only one in the United States that meets Federal Railroad Administration (FRA) standards for operation at over 110 mph—incorporates 500 tons of new rail and more than 1,000 tons of new concrete ties per mile. The rolling stock and signalling system are also highly specialized. Between Washington and New Haven, trains are pulled by the only high-speed electric traction system in the country. The signal system includes both wayside and in-cab speed indications and permits bidirectional operations on most main tracks. Stations are carefully planned to be efficient and accessible. And the track and trains require modern, specialized equipment and facilities for proper maintenance.

Two decisions are basic determinants of the capital cost of any projected high-speed rail system:

☐ Is the railroad to be a new facility or is it to be a rehabilitated existing facility?

☐ Is the railroad to be a dedicated (single-purpose) facility, or will it carry different kinds of traffic, such as commuter, freight, and high-speed intercity?

Most of the high-speed rail proposals now attracting attention in the United States assume construction of a brand new, dedicated facility. In this respect they resemble the Japanese *Shinkansen*, which runs on special tracks and shares only station facilities with conventional rail services. While this is the most exciting engineering challenge, it is by no means the only alternative. At the other end of the scale, British high-speed trains, like those in the U.S. Northeast Corridor, travel on rehabilitated right-of-way shared with other rail service. The French *TGV* system may have the best of both approaches. One of its major innovations is the adroit use of the existing right-of-way to enter and leave urban centers; new right-of-way was built only in the rural areas.

Surprising Economics

The question to ask first about every high-speed rail proposal is this: What does its speed really cost us? The answers are often surprising. The time saved by increasing the speed of a train is very much subject to the law of diminishing returns. As the speed increases, the time required to travel a given distance decreases by smaller and smaller amounts. It works this way: At any particular speed S (in miles per hour), the time in seconds required to traverse one mile is given by the expression (3600/S). Thus, for example, it takes 60 seconds—or 3600/60—for a train to travel one mile at 60 mph. If the speed of the train is increased by a 60-mph increment to 120 mph, the time to travel one mile is 3600/120, or 30 seconds, and the time savings is 30 seconds. On the other hand, when the speed of the train is increased another 30 mph, to 150 mph, the time to travel one mile is 3600/150, or 24 seconds, which means a time savings of only 6 seconds.

The lesson is not necessarily that high speed is undesirable. It is, instead, that the advantage of high speed depends upon going long distances without stopping and upon avoiding low speed for any distance. This is why the promising opportunities for high-speed rail are on routes at least 200 miles long with only a few intermediate stops.

DIAGRAMS: OMNIGRAPHICS

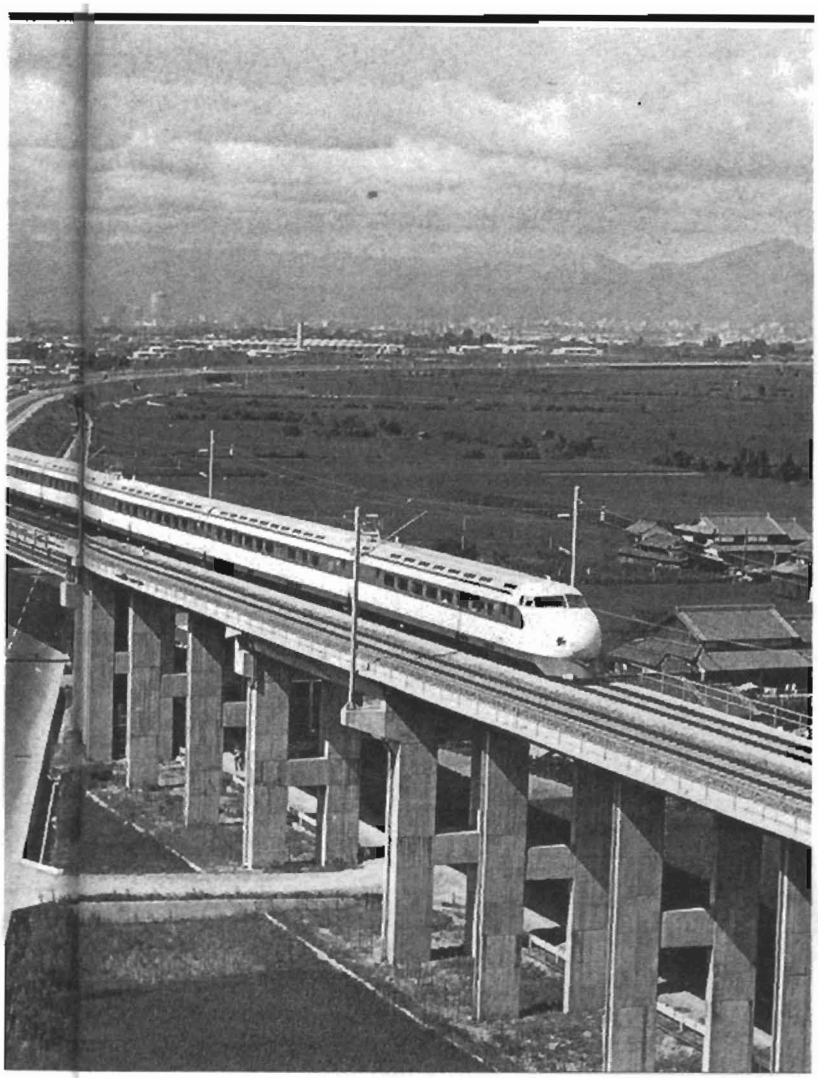
Also, as the speed for which systems are designed rises, the cost of building them increases—in most cases disproportionately.

One reason is that keeping the centrifugal force on passengers to a tolerable level at high speeds requires the very gentlest curves. On the *TGV* and the newer sections of the *Shinkansen*, the sharpest curve permitted for trains operating at up to 170 mph is an arc of a circle whose diameter is about eight kilometers—a very close approximation of a straight line. Furthermore, the restrictions on gradients for most high-speed rail designs have been severe—no more than 1 percent (one foot of rise or fall in 100 feet of distance). Together, the limits on curvature and gradient mean that high-speed rail requires extensive land acquisition and expensive cutting, filling, bridging, and tunneling—especially in hilly areas. The French, however, have made an important breakthrough in high-speed rail design, relaxing the gradient requirement, though not the curvature limit, in the innovative design of the *TGV*. Short stretches of track with gradients as steep as 3.5 percent were permitted between Paris and Lyon, and equipment for the planned *TGV* Atlantique between Paris and Bordeaux will be designed for grades up to 5 percent. Such gradients are made possible by electric propulsion with somewhat more horsepower than is conventional, and a willingness to let the train alter its speed as it travels up and down grades.

The requirements on track precision are dramatically greater for high-speed rail, too. Slow-moving freight trains and conventional commuter service can be operated with relatively large discrepancies between the level of one rail and another. FRA standards permit a maximum discrepancy of 1.25 inches for 80-mph operation. But the French require discrepancies of no more than 0.16 inches for the 170-mph speeds of the *TGV*, and the FRA standard for 120 mph is 0.5 inches. There is nothing impossible about such requirements. Satisfying them is, however, very expensive.

Several different high-speed propulsion systems have now been tested, and the economic trade-offs between them are therefore well known. The initial cost of diesel power, such as used by the British high-speed train, is lower than that of electric propulsion: no overhead wiring or wayside transformers are needed. But the engine is mechanically more complex, uses more energy (which can be obtained only from liquid fuel), and offers much lower acceleration, especially at high speeds. Electric propulsion, on the other hand, is quieter and non-polluting, and the power can be efficiently obtained from many different fuels. When several units throughout a train are electric powered, as they are on the *Shinkansen*, high initial cost due to complexity is offset by the greater reliability that comes with redundancy and better traction. However, with either kind of equipment, the trains themselves represent, at most, only about 20 percent of the capital cost of a high-speed rail system.

More exotic technology may be available in the future, in the form of two schemes for magnetic levitation that are now in the development stage. Japanese National Railways (JNR) is studying a system with on-board superconducting magnets that, acting together with passive coils embedded in a guideway, lift, guide, and propel a train. German engineers are working on a system that would suspend the train between attracting magnets in train and guideway and use feedback to maintain the train's position. Both systems would require a specialized guideway, but they would make possible speeds of 200 to 250 mph or more—faster than is



Japan's Tokyo-to-Osaka *Shinkansen* is the oldest of the world's few high-speed trains. It is also by far the most heavily patronized, carrying 125 to 150 million passenger-trips a year. No comparable demand is forecast for any high-speed route in the U.S.

likely with our present steel-wheel-on-steel-rail technology. Moreover, since there would be no physical contact between train and guideway, maintenance and operating costs might be lower.

The Japanese have been testing their magnetic levitation system for over eight years, and all of the problems identified so far appear solvable. The Germans are also optimistic, though they have only begun the testing cycle. But neither system is likely to be ready for another two to five years. Only then will the new technology face the weather, maintenance, and service problems that tests somehow never adequately simulate.

Predicting Operating Cost—the Easy Part

The higher capital cost of conventional high-speed rail is accompanied by higher operating cost. Because the track geometry must be so precise, track maintenance for high-speed rail is expensive. And because the forces that the equipment exerts on the track increase exponentially with speed, maintenance cost is extremely sensitive to the speed at which the system is operated. Modest reduction in costs may be possible if new trains can be designed so that they are lighter, have less unsprung weight—that is, a higher proportion of their weight carried above the springs—and have their total weight distributed equally among many wheels.

Another problem is that at high speeds (over 100 mph) energy use per mile increases with the square of the speed. In other words, boosting speed from 90 to 125 mph could double fuel consumption. But designs involving less weight and air resistance can improve fuel economy. For example, at 170 mph the *TGV* uses only as much energy as Amtrak's Metroliner at 120 mph. And though energy is always a significant expense (20 to 30 percent of total operating cost), every high-speed rail system has a substantial efficiency advantage over its principal competition: Metroliner and *Shinkansen* can carry a given number of passengers for about one-sixth as much energy per mile as a narrow-body aircraft.

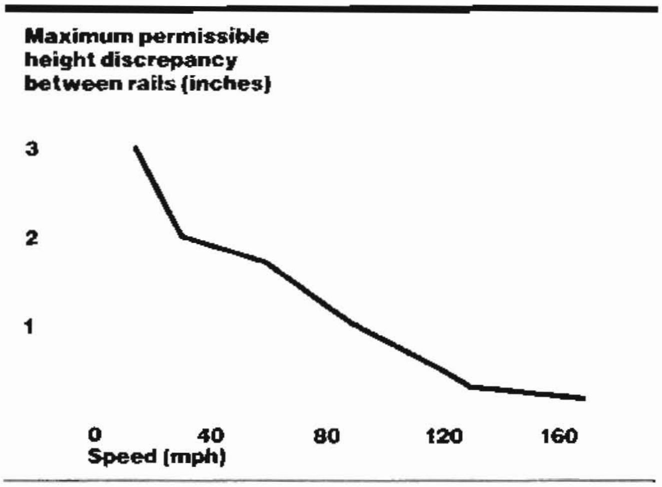
There are other cost advantages of high-speed rail. The French have demonstrated very impressive crew productivity on the *TGV*, where some trains are operated with three-person crews—one-half to one-third the complement on other high-speed systems. Furthermore, ticketing for high-speed rail is simple and easily automated: there are likely to be few stops and few auxiliary services such as parlor or sleeping cars.

Revenue—Hard to Forecast

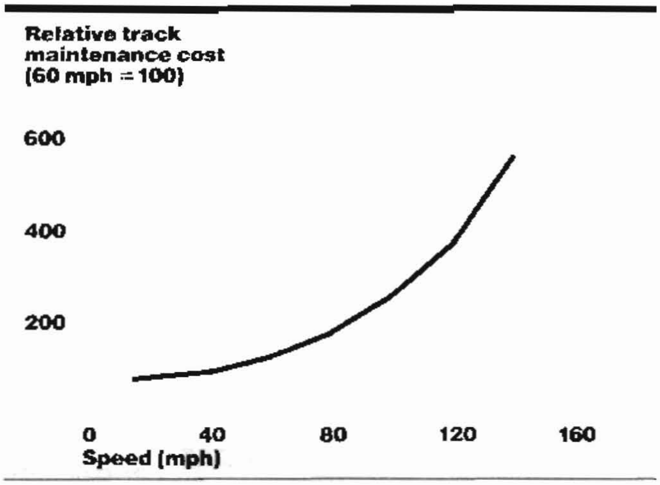
Our ability to forecast the demand for high-speed rail service, and therefore the income that it may generate, is far poorer than our ability to forecast capital and operating cost. Indeed, some demand factors are unknowable before service actually begins.

Forecasting traffic has been easier overseas than in the United States. In both Japan and France, the existing rail capacity was saturated when high-speed rail was inaugurated. The main question was how much of that traffic the *Shinkansen* and the *TGV* should accommodate. By comparison, the Metroliner presented several difficult forecasting problems. One of these was how to predict demand for an improved service that had never been fully utilized in its unimproved state. Another was how to calculate the effect of competing carriers. For example, the 1971 forecasts of the office of the Secretary of Transportation and even the 1977 and 1978 FRA

PHOTO: CONSULATE GENERAL OF JAPAN (NEW YORK)



Top: The faster trains are to travel on a track, the smaller must be any discrepancies between the heights of the two rails.



Bottom: High-speed operation puts a great deal of stress on the precision-engineered track. As a result, maintenance is costly.

forecasts could not have taken into account the competition created by lower air fares resulting from airline deregulation.

A third issue lies in assessing the extent to which a new travel mode may increase the total travel along a route. An exciting new form of transportation indisputably produces some new travelers. But only heroic investors will put up money on the basis of such induced demand.

Building on Foreign Experience

Many analysts have tried to compare the economic performance of high-speed rail in the United States with that overseas. Their results are at best imprecise because conditions vary between projects in ways that are hard to evaluate. Converting foreign currencies into the dollars of many different years is also difficult. Yet some general conclusions are possible, and foreign experience is particularly helpful in judging indirect benefits and costs.

All available evidence suggests skepticism about any proposals for new systems with capital costs of less than $10 to $20 million per mile. The Japanese report spending $30 to $40 million per mile between 1975 and 1982 to build the new *Shinkansen* systems north of Tokyo. Merely rehabilitating the Washington-New York segment of the Northeast Corridor cost about $5 million a mile. And while the French claim a cost of only $4 million per mile for the *TGV*, they benefited from using existing stations, urban track, and maintenance facilities that would normally not be available to builders of new systems in the United States.

Another fact is clear from these comparisons: construction cost per mile goes down very little as the length of a high-speed rail line increases.

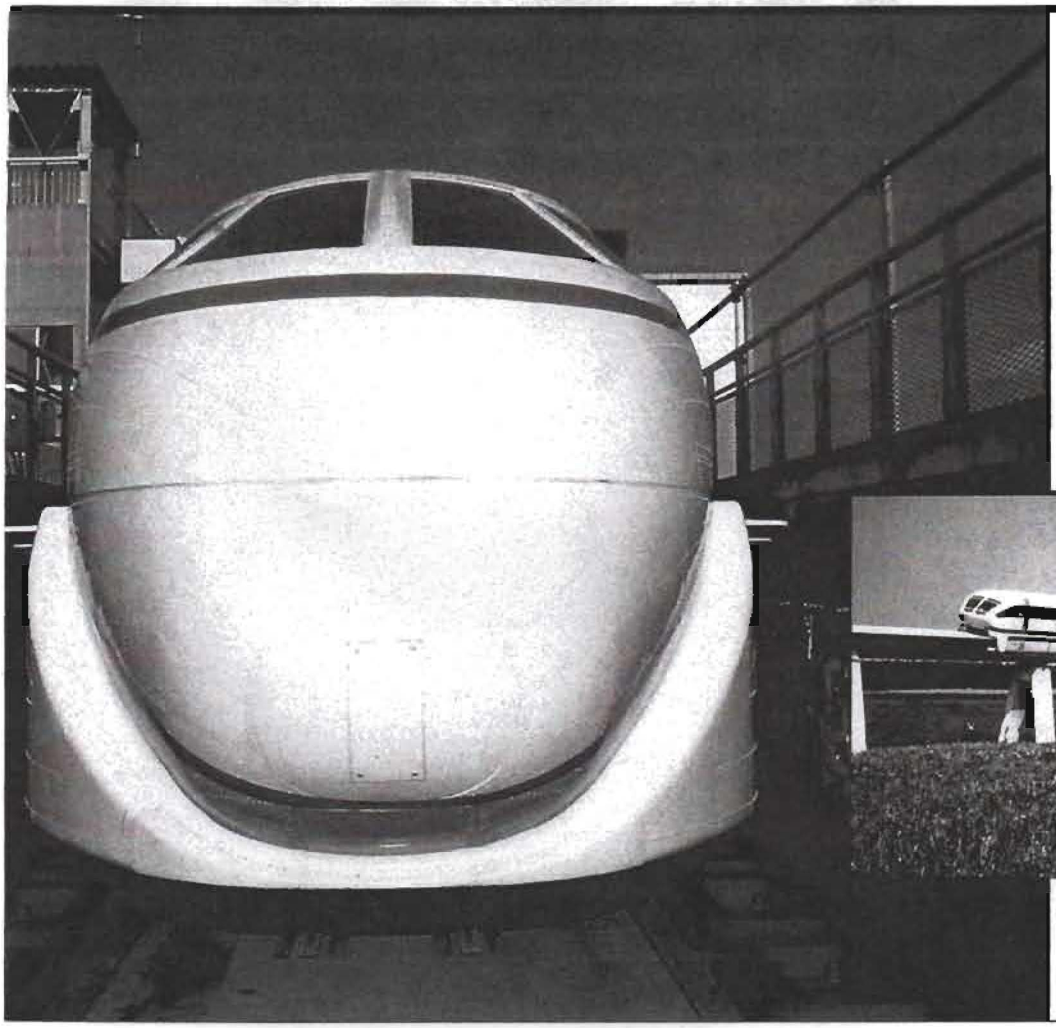
On the other hand, there are major economies of scale in operations. Costs per passenger mile appear to decrease sharply as the number of passengers increases. This works to the advantage of the *Shinkansen*, where annual ridership on the highly profitable Tokyo-Hakata line is a prodigious 125 to 150 million passenger trips. The *TGV* between Paris and Lyon serves 16 million passenger trips a year. However, in the New York to Washington segment of the Northeast Corridor—where ridership is probably the most intensive of any route in the United States—the total is only about 8 million passenger trips a year. Clearly, we should be very skeptical of estimates that equate the demand for high-speed rail in the United States with that in Europe and Japan.

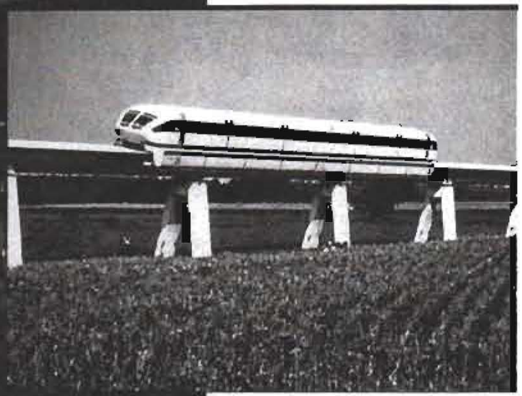
On the basis of revenue generated per dollar of investment—the primary determinant of an investment's ability to earn an adequate return—the *Shinkansen* line linking Tokyo, Kyoto, and Hakata and the *TGV* between Paris and Lyon stand far above other existing high-speed rail systems. Both earn about 20 cents in revenue per dollar of investment. Nothing else is even close, except the promoters' projections for the proposed Los Angeles-San Diego line. Significantly, this level of earnings may be the minimum a high-speed system needs to operate without some way of directly capturing the value of indirect benefits.

The Lure of Indirect Benefits

In addition to tangible revenues, promoters often cite indirect benefits that may offset the costs of high-speed rail. These include making travel safer and more reliable, reducing environmental impacts, stimulating economic development, and creating jobs.

High-speed rail systems have uniformly better pas-





Trains that use magnetic levitation to lift themselves off special guideways are now being tested in Japan and Germany (inset). But the 200-to-250-mph service that the sponsors of such trains promise will not be commercially available for at least a decade.

senger safety records than air or, especially, automobile transport. It is not clear, however, whether travelers' decisions between competing forms of transportation are affected by this safety record.

All-weather reliability is another noteworthy advantage of high-speed rail. With proper signalling and control systems, railroad operations can run efficiently despite all but the most severe weather conditions. During much of the day, JNR operates ten 16-car *Shinkansen* trains per hour in each direction between Tokyo and Osaka, and an astonishing 95 percent of them are on time.

Experience in Japan and France shows that on a per-passenger basis high-speed rail affects the environment much less than competing modes of travel. Though railroad noise has brought complaints in urban areas, most people acknowledge that high-speed rail pollutes the air less than do automobiles and causes less visual intrusion. In Florida, environmentalists advocate high-speed rail service between the major centers of Tampa, Orlando, and Miami as a tool to guide future development away from ecologically fragile coastal areas.

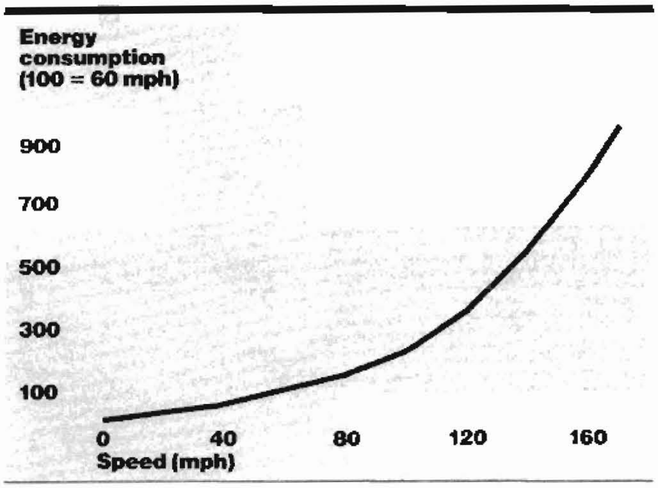
Rail systems stimulate intensive economic development around stations, and thus can help revitalize the centers of cities in which the stations are situated. The *Shinkansen* has already done so in Japan, as almost any traveler can testify, but we in the United States have been comparatively slow to realize the economic potential of railroad stations. We are catching up, however. Recent visitors to Providence, Wilmington, New Haven, Newark, or Baltimore can testify to the role that the rail station is expected to play in these urban centers.

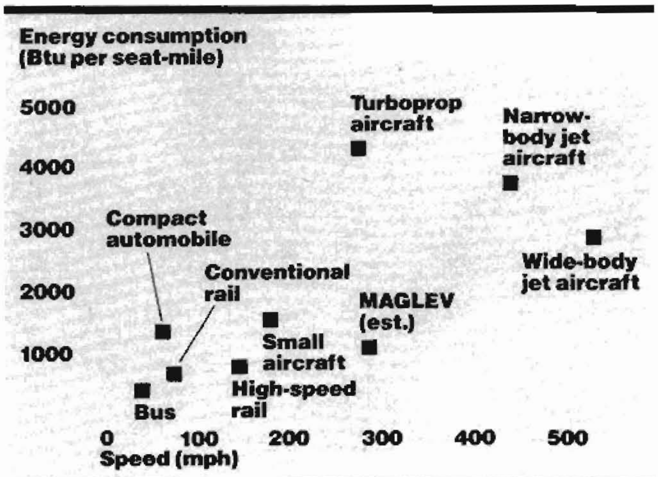
Supporters of Amtrak and the *TGV* have argued that efficient, low-cost passenger service assures mobility to people who otherwise could not travel. My experience on the *Shinkansen* indicates that all income levels do make intensive use of the train. Thus wider distribution of travel opportunities may indeed be an intangible benefit of high-speed rail. On the other hand, the proposition that construction and operation of a high-speed rail system will create new jobs deserves careful examination: some other project might create just as many.

Finally, high-speed rail systems are often advocated for their "image" value. Promoters in both Florida and Las Vegas have argued that high-speed

PHOTOS: JAPANESE NATIONAL RAILWAYS, LOUIS S. THOMPSON

At high speeds—over 100 mph—energy use per mile is proportional to the square of the speed (top). But even so, a 120-mph train occupies a special place in the spectrum of transportation options. Though not as fast as aircraft, such a train is faster and more economical per passenger mile than any competing form of transport (below).





rail would attract tourists, and no pictorial on Japan or France is complete without shots of the *Shinkansen* or the *TGV*. But the economic benefit can be determined only by those who are very familiar with the local economy.

Some of the intangible economic factors of high-speed rail relate to effects on the transportation infrastructure, and such effects cannot easily be given monetary value. Consider, for example, the need for easy public access to high-speed rail stations. According to JNR estimates, up to 75 percent of *Shinkansen* riders reach and leave their trains by mass transit, presumably increasing mass-transit patronage. But in the United States, high-speed rail has not been able to take such mass-transit facilities for granted. Amtrak and the Federal Railroad Administration had to join with local communities in building parking lots to encourage use of the trains.

On the other hand, in some situations high-speed rail may save money by reducing the need for public investment in alternative transportation. One argument for the Los Angeles-to-San Diego high-speed line has been that trains will cut traffic on the overtaxed interstate highway between those points and thus eliminate the need for new highway construction. The same argument has been made in Florida, where major highways linking Miami, Orlando, and Tampa are forecast to be saturated by the turn of the century.

The Institutional Imperatives

All these issues bear on the answer to the ultimate questions: Who would want to build and operate a high-speed rail system in the United States and why? For whom are the benefits of high-speed rail service likely to be greater than the costs?

Building and operating a high-speed railroad will never be anything like a typical private-sector construction project with a specified client, known problems, and a given budget. Instead, high-speed rail systems are "mega-projects" in the sense that they have social as well as economic objectives. They affect virtually every economic and social activity in every community involved. They change lives, altering the way people use or perceive natural, cultural, and historical resources. Consequently, such projects are inevitable targets for conflicting political and social pressures. Indeed, no one can define in advance all the impacts of any particular high-speed rail project and therefore all the institutional issues that will arise from it. The siting of stations and rights-of-way is likely to be controversial. Even schedules can be matters of public debate. Investors, engineers, and managers have to make social as well as technical judgments, taking responsibilities outside their professional fields and beyond their normal experience. High-speed rail systems simply cannot be built or operated unless all relevant public institutions are involved in some way.

In the final analysis, institutional issues will remain unresolved until the benefits received by each institution involved are roughly equal to or greater than the costs each incurs. Achieving this balance was no easy task even in Europe and Japan, where a central government has traditionally operated a centralized railroad system. A solution is still more difficult in the United States, where we have sought to maintain distinctions between the roles of the private sector and those of the various public-sector agencies.

The federal policy toward the high-speed rail systems now being proposed is very clear. Most high-speed systems would operate in one or at most two

Continued on page 70

CONTINUED FROM PAGE 41

states, and virtually all of their benefits would be realized at the local or state level. There is, therefore, no case to be made for federal financing. In fact, there is a clear advantage to keeping the decision making in local and state hands: groups at these levels are best equipped to evaluate the needs that a high-speed rail system could satisfy.

The federal role appears best confined to advice, facilitation, and clearance. For example, the Federal Railroad Administration has, or has access to, more information on high-speed rail than any other public or private group. The FRA has the experience of carrying out the Northeast Corridor Project and has financed most of the preliminary studies of high-speed rail in the United States. The agency is ideally suited to provide advice to those involved in high-speed rail issues and can readily bring interested parties together.

As with other major construction projects requiring federal clearance, environmental impacts will be weighed at the state and federal levels, and the cost of meeting environmental regulatory standards will be included in the capital requirements for any high-speed rail project. The private owner-operator will also be responsible for meeting federal safety regulations. And finally, the economic development that results from the new rail system will be regulated at the local and state levels.

The major public participants in any new high-speed rail project will probably be the states within which the line is to operate. States might contribute toward construction costs, but indirect assistance is more likely—low-interest financing, free use of existing rights-of-way, aids to property acquisition, and tax abatements.

Local governments may finance and operate some parts of any new high-speed rail system. In New Jersey, the Atlantic County Improvement Authority will contribute funds toward a $15 million Atlantic City terminal for the proposed Philadelphia-to-Atlantic City Amtrak extension. The American High-Speed Rail Corp. requested similar commitments from local governments in the Los Angeles-to-San Diego corridor.

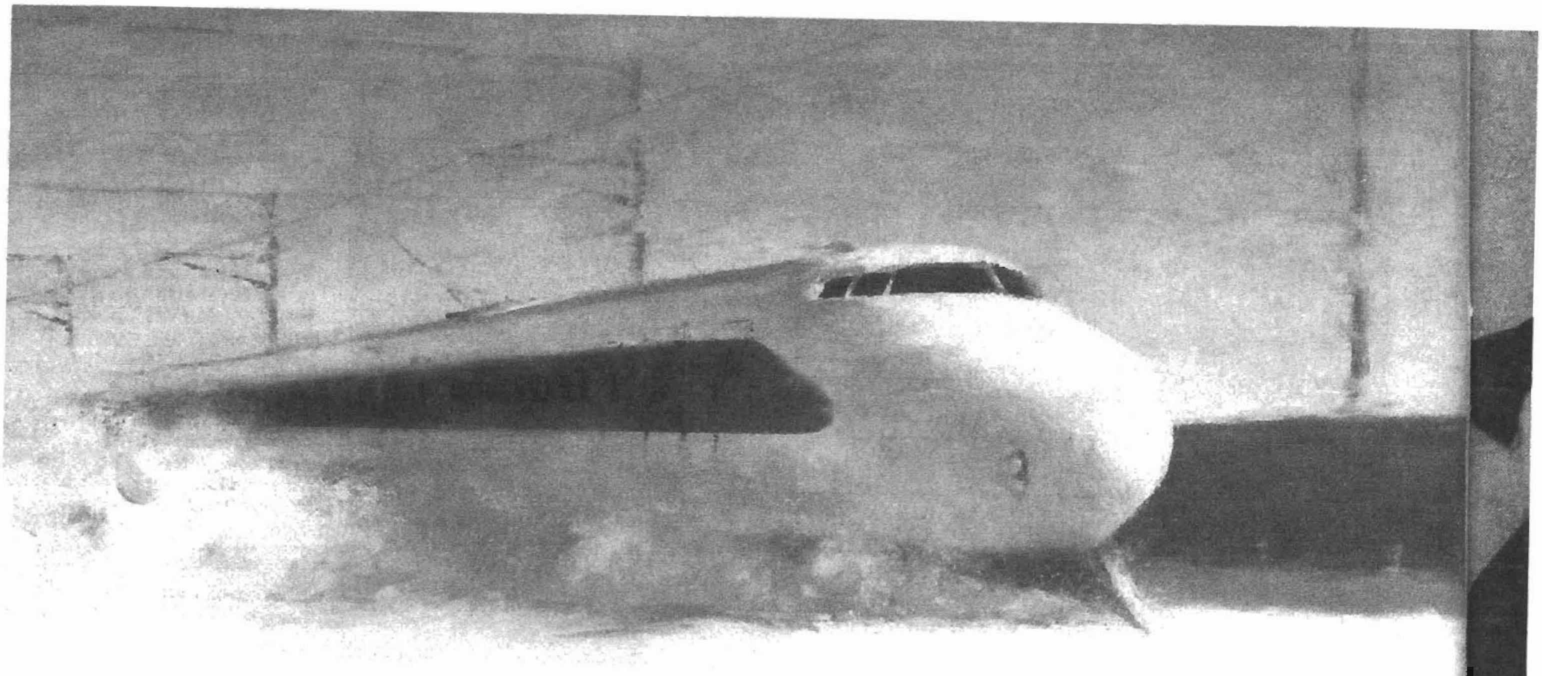
High-speed rail will become viable only when the public sector and private investors find a way to value indirect benefits highly enough to make the sum of *all* benefits, public and private, direct and indirect, equal the costs, which will certainly exceed $5 million per mile and may be more than twice that. The returns from operating income alone are not likely to justify such a large cost to any private investor. Indeed, no high-speed rail project has been undertaken wholly by the private sector anywhere in the world. The Northeast Corridor Project, for example, was largely funded and managed by the FRA. Much of the construction was carried out by Amtrak. Significant financial contributions, in the form of cost-sharing agreements, came from state and local governments and private companies.

Finally, one problem will remain to be solved before appropriate financing can be obtained: some public agency must assure long-term continuity in the environment where any entrepreneur will build and operate a high-speed rail system. High-speed rail involves billions of dollars invested over hundreds of miles and affects millions of people. Such a system and its ancillary development will require upwards of a decade to build, and its investors may not receive adequate financial returns in less than a quarter of a century of operations. Many political jurisdictions will be involved throughout both periods, and the investors in the system must be protected from capricious changes in public attitudes and public-sector regulation.

Of all the states in which high-speed rail projects have been proposed, Florida is perhaps the farthest along in taking a truly creative approach to this problem. The Florida High-Speed Rail Commission has established close relations with other state agencies and with city and county agencies affected by the high-speed rail proposal. Hearings have been held throughout Florida, and by this summer the Commission expects to invite private-sector proposals for construction and operation of a system linking Miami, Orlando, and Tampa. Indeed, Florida will be this country's first good test of whether high-speed rail systems can acceptably balance tangible and intangible benefits and costs.

There are encouraging precedents, notably the original Tokyo-to-Osaka line in Japan and the *TGV* between Paris and Lyon: the economic result of both appears to be very positive. In addition, government-sponsored studies evaluating the U.S. Northeast Corridor and the high-speed train in Britain conclude that the overall benefits of high-speed rail should exceed the costs.

But the new proposals are difficult to judge because the tangible and intangible factors involved are so numerous. The juries are still out.



The Japanese National Railroads' *Shinkansen* between Tokyo and Hakata carries far more passengers than any other high-speed train in the world. Only it and the French *Train à Grande Vitesse (TGV)* are generating enough income to operate without subsidy. Most other existing and proposed high-speed lines can be operated profitably only if a high value is assigned to such indirect benefits as cleaner air, lessened environmental impact, safer and more reliable transportation, and greater midtown prosperity.

		Miles of line	Average end-to-end speed (mph)	Total investment (billions of 1985 dollars)	Investment per mile (millions of 1985 dollars)	Annual passenger-miles (millions)	Operating cost (cents per passenger-mile	Revenue per dollar invested (cents)
OPERATING HIGH-SPEED SYSTEMS								
Japanese National Railways Shinkansen								
Tokyo-Osaka-Hakata	*Electric power, dedicated track*	668	100	$18.3	$27.5	26,155	7.5c	19.4c
Tokyo-Morioka	*Electric power, dedicated track*	290	94	10.7	36.7	3,713	6.3	5.3
Tokyo-Niigata	*Electric power, dedicated track*	169	97	5.3	39.0	1,404	9.1	4.[illegible]
French National Railways TGV								
Paris-Lyon	*Electric power, dedicated and shared track*	265	130	1.7	6.8	4,900	2.7	20.3
Amtrak (U.S.) Metroliner								
Boston-Washington	*Electric and diesel power, shared track*	456	80* 56#	2.8	6.2	1,207	12.8	7.2
PROPOSED U.S. HIGH-SPEED SYSTEMS								
New York-Vermont-Quebec								
New York-Montreal	*Electric power, dedicated and shared track*	362	116	2.4	6.7	466	11.8	3.5
Ohio								
Cleveland-Columbus-Cincinnati	*Electric power, dedicated track*	330	100	2.1	6.3	670	6.8	7.2
Florida								
Tampa-Orlando-Miami HSR	*Electric power, dedicated track*	314	123	2.8	8.8	415	15.0	3.2
Tampa-Orlando-Miami MAGLEV	*Electric power, dedicated guideway*	314	196	5.0	15.9	465	17.5	2.0
Pennsylvania								
Philadelphia-Pittsburgh HSR	*Electric power, dedicated track*	314	96	9.3	29.6	985	13.5	1.7
Philadelphia-Pittsburgh MAGLEV	*Electric power, dedicated guideway*	314	120	13.0	41.3	1,216	14.6	1.6
California								
Los Angeles-San Diego HSR	*Electric power, dedicated track*	132	127	3.0	25.3	1,793	5.4	15.4
Illinois-Michigan								
Chicago-Detroit HSR	*Diesel power, shared track*	280	79	0.7	2.6	498	9.0	10.5
Chicago-Detroit HSR	*Electric power, dedicated track*	280	104	1.8	6.4	607	7.7	5.5
Chicago-Detroit MAGLEV	*Electric power, dedicated guideway*	280	166	2.9	10.3	881	10.6	5.2

*Washington-New York
#New York-Boston