The Future's Already Here

# High-Speed Rail Passenger Service: Technology and Application

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In the total transportation spectrum the all-new high-speed rail systems have carved a distinctive technological niche. They alone cover the zone between 55-60 mph and 165 mph. Trains such as the British Rail HST (High-Speed Train) and Amtrak Metroliners operate in the 55- to 120-mph sector while the Japanese Shinkansen (New Railway) and the French TGV [Tres Grande Vitesse (Very Great Speed)] run in the 100- to 165-mph sector. This grouping is determined by the rate of speed called for by the owner/operators and then is firmly established by engineering design.

## DESIGN AND SPEED

When a track system has been designed for high-speed operation, it must be either straight and level or designed in all dimensions to take care of the force vectors in both gradient and curvature. Curves on some high-speed rail system segments have been constructed with superelevation of 7 in, in order to guide the train into a new heading safely, comfortably, and with near equilibrium of forces on both rails, without reducing speed. The British HST and Amtrak Metroliners travel at speeds up to 120 mph on sections of reworked and improved rail lines. This has been possible for Metroliners because Amtrak owns the right-of-way between Washington, D.C., and New York City. The Shinkansen in Japan and TGV in France operate on new specially constructed lines. If very-high-speed trains are to operate in the United States outside of the Northeast Corridor, they will have to have "all-new" track, or additional segments of the existing rail systems will have to be completely redesigned. However, U.S. heavy-freight rail operators, who do a $32 billion/year business, are reluctant to accept such changes nor should they be required to accept such changes. The only way a high-speed rail system will operate in this country will be on all-new track as is currently the case in Japan and France.

Since speed is the basic parameter that dictates the design of the system, how then is the speed regime selected? Is it simply some arbitrary set of numbers or is it a more formalized choice?

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The owner/operator wants to get people from A to B as fast as possible consistent with economy and safety. Trains have run at more than 200 mph and, in theory, wheels could be rolled on track at 500-700 mph. But, neither of these top speeds is economical—even if running the trains could be made safe and reliable. The decision to accept a certain top speed in commercial operations must be a compromise between the time gained by faster service and the cost of the additional power to achieve that speed. Consider the following example.

A 200-mile trip at 50 mph takes 4 h. At 100 mph it takes only 2 h. This is a significant time saving at an acceptable increase in cost. At 125 mph the trip takes 96 min and saves 24 min over 100 mph. At 150 mph the trip takes 80 min and saves 16 min. At 175 mph the elapsed time is 68 min, saving 12 min. At 200 mph the elapsed time is 60 min, saving 8, and at 225 mph the saving is 7 min. Thus, as the speed increases in even 25-mph increments, the elapsed

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time is reduced by ever-decreasing time increments (see Figure 1). Above 175 mph the saving on a 200-mile trip segment is not worth the increased cost and on normal shorter trip segments, e.g., Washington to Baltimore (38 miles), the difference in time would be minimal.

Furthermore, the traction power required to overcome aerodynamic drag increases as the cube of the speed. This is a heavy penalty to pay for a slight time saving. Also, many other costs, such as track construction and maintenance, rolling stock design and manufacture, and catenary construction, increase drastically with higher speed.

All this proves that there is a reasonable range of top speeds for a steel-wheel-on-steel-rail set of vehicles that is dictated by the costs versus the benefits in time saved. The French National Railroads engineers, when designing the TGV line, chose 162 mph as the top speed. The Japanese National Railway engineers chose 130 mph for the first line—Tokyo to Osaka—and have since raised it to 150 mph for the high-speed line extensions.

## CHALLENGE TO RAIL TECHNOLOGY

When the original group of Japanese planners proposed that a railway system could be constructed to carry a heavy volume of passengers between Tokyo and Osaka—that country's

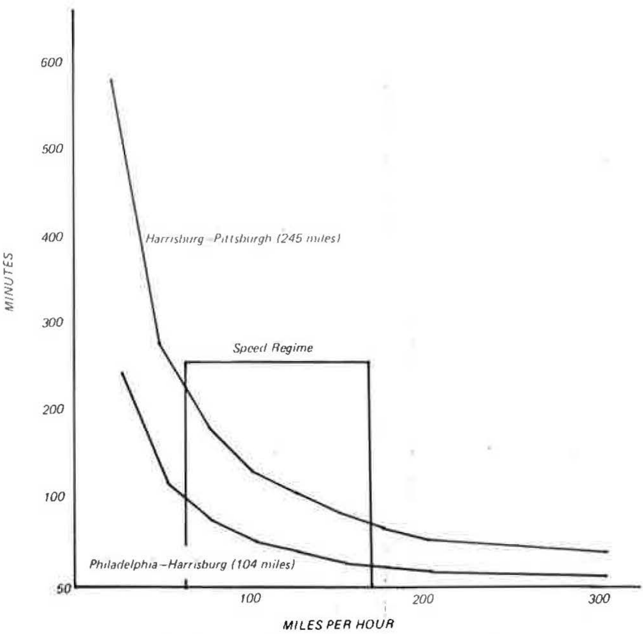



**Figure 1. Graph shows that rate of speed increases in even increments, while elapsed time decreases unevenly. The projected Philadelphia-Harrisburg run takes 50 min and the projected Harrisburg-Pittsburgh run, 120 min.**

main travel artery (320 miles)—at an average speed of 100 mph, they were challenging the established state of the art of century-old railroad technology. They accomplished their goals by developing the Shinkansen as a carefully engineered total system. As a result, the Shinkansen is now considered by the Japanese to be a national treasure. It not only provides fast, economical travel in total safety (not a single casualty with 2 billion passengers carried in 18 years) for hundreds of millions of people in densely populated areas, but also has been extended, in a two-pronged direction, north of Tokyo, into areas of the country less densely populated than the Tokyo-Osaka corridor as a nation-building activity. Even these new routes have been successful beyond all expectations, and the coastal route is being extended under the sea to the north island of Hokkaido.

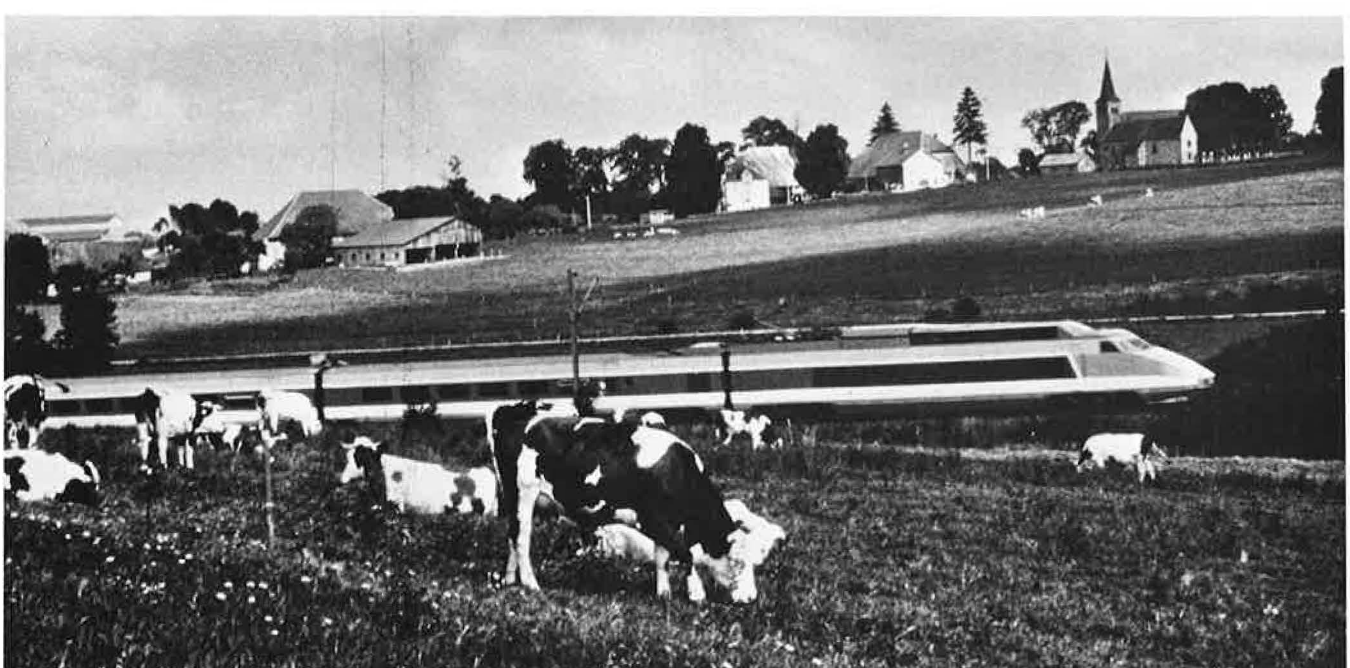
The success of these high-speed rail systems in Japan and in France was not derived from speed alone. These two countries have discovered the synergism that spells success. When the high-speed train is operated as part of a total system, the result is attractive to millions of riders.

## SOME ADVANTAGES

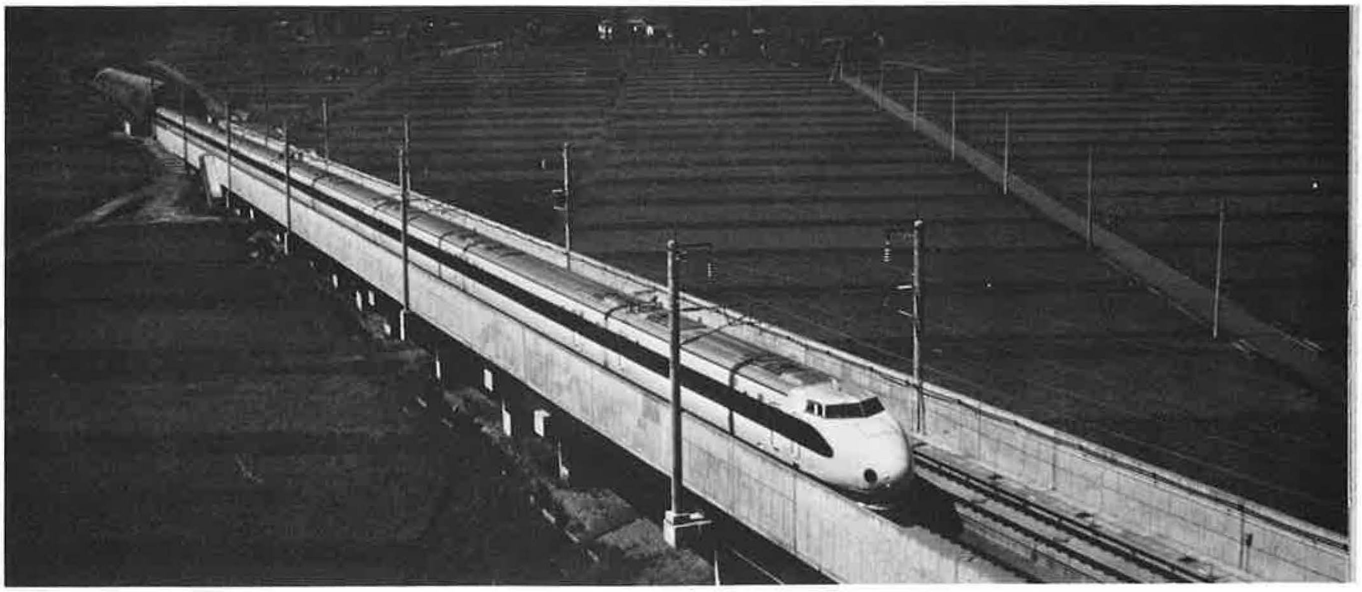
Because all components of the system are optimal, total system efficiency is high. The unit cost per passenger mile of operations is low because of the large passenger volumes. The profitability of the Shinkansen system has been demonstrated for years. The cost of moving a passenger on the Shinkansen is 4.9 cents/mile. While the prospect of such great passenger volumes in the United States may not be high, sufficient passengers should use a high-speed rail system to permit costs below the cost of automobile travel, which exceeds 30 cents/mile; the price of air travel, from 15 to 53 cents/passenger mile; and travel by motor bus, from 8 to 11 cents/passenger mile.

In March 1979, Alan S. Boyd, then president of the National Railroad Passenger Corporation (Amtrak) stated in testimony before the U.S. Congress: "I believe that it is incumbent upon Congress at this juncture to carefully reevaluate its commitment to high-speed rail passenger service in the (Northeast) Corridor, and it is especially important that this be done in conjunction with the proposed restructuring of the national Amtrak system."

During November of that same year, Boyd accepted an invitation from the president of the Japanese National Railway



**A tranquil pastoral scene appears "invaded" by the futuristic-looking French National Railroads TGV, which can travel at speeds of up to 165 mph. (Photo courtesy of French National Railroads)**



**Juxtaposed against farmland is one of the Japanese Shinkansen high-speed trains. Japanese National Railway operates in both densely populated and rural areas.**


**British Rail's HST travels at speeds up to 120 mph. It operates primarily between large metropolitan centers such as London to Edinburgh.**


**An Amtrak Express Metroliner, powered by an AEM-7 high-speed electric locomotive and equipped with new Amfleet II cars, dashes toward Washington on its way from New York. Amfleet II cars can be distinguished from the original Amfleet equipment by their larger windows and vestibules located in only one end of the car. (Amtrak photo)**

to visit Tokyo and to ride on the Shinkansen and be fully briefed on its operations, finances, and plans. A few days after his return from Tokyo, Boyd summed up his views in a speech delivered in Chicago:

> "I emphasize the Shinkansen 'system' because that is the most accurate way to describe it and to underscore why it is different. The Shinkansen rolling stock is impressive, but there are very impressive trains in other countries. The Shinkansen right-of-way, roadbed, and track are impressive, but certain passenger rail sections in other countries may be as well designed. The Shinkansen central traffic control, computerization, and management are excellent, as they are in other countries. Its maintenance is extraordinarily efficient, and some other countries may match that. It is when you put all of this together into a fully integrated system that you discover, beyond all doubt, (that) the Shinkansen system has no equal. It is well-designed, well-organized, well-supported, and well-managed."

## CONCLUSION

If high-speed passenger rail service is to be used in the United States, two things are clear. First, new tracks must be built since the problems of superelevation prevent freight and passenger service from operating in different speed regimes on the same track. Second, the construction of new track must be done as part of an integrally designed system—i.e., track, vehicles, controls, stations, and operating practices with all their interfaces designed as subsystems of the overall system. Neither of these two situations is insurmountable as other nations have demonstrated. In fact, they have shown that the future of high-speed rail technology is already with us.

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