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Magnetic Levitation (Maglev) Trains: Technical Background, Cost Estimates, and Recent Developments

Since the 1990s, the U.S. Department of Transportation has provided funding to support development and construction of a train system operated by magnetic levitation (maglev). Maglev trains use magnetic forces to create a cushion of space between a vehicle and its guideway, reducing friction and permitting top speeds in excess of 300 miles per hour, which are not achievable by conventional wheel-on-rail trains.

The high speeds reached by maglev could theoretically shorten some intercity trips to the length of a local transit ride. Maglev trains can travel roughly 50% faster than the fastest high-speed rail trains currently in use abroad and nearly twice the top speed of Amtrak's Acela, currently the fastest passenger train in the United States. At full speed, maglev trains could offer travel times competitive with airline flights at distances of up to 750 miles. At that range, maglev could serve city pairs too far apart to have merited serious consideration for new high-speed rail lines, such as Chicago-Washington, DC (700 miles), or Atlanta-Miami (660 miles).

Despite this advantage, maglev technology has seen limited real-world use since its first demonstrations in the 1980s. There is one high-speed maglev line in commercial service today, an express airport shuttle in Shanghai, China. Very short lines using maglev technology but running at much lower speeds are operating in Korea and Japan. A longer intercity line is in early construction stages in Japan, but is not expected to open before the late 2020s, and another has been proposed between Hong Kong and Guangzhou, China.

There are two main reasons, often interrelated, that few maglev lines have been built: cost and lack of interoperability. Maglev trains require very straight and level tracks to maintain high speeds. This necessitates extensive viaducts and tunneling, making construction costly. Maglev vehicles are not compatible with conventional rail infrastructure, making it difficult if not impossible for maglev trains to make use of existing terminals and rights-of-way in densely developed city centers. This too could create the need for expensive tunneling projects, or else lead developers to build terminals outside city centers, making it less convenient.

Maglev Within U.S. Transportation Policy

Federally funded research in maglev technology can be traced back to the 1970s. Since the 1990s, Congress has authorized funding for maglev research and demonstration projects in several surface transportation laws. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) created a maglev program office to be run jointly by the U.S. Department of Transportation and the U.S. Army Assistant Secretary for Civil Works, and authorized $500 million from the Highway Trust Fund for the program. Much of this funding was never spent. The Transportation Equity Act for the 21st Century of 1998 (TEA-21) then codified a maglev deployment program in law (23 U.S.C. §322), under which seven projects were later identified for further study. TEA-21's successor, the Safe, Accountable, Flexible, Efficient Transportation Equity Act of 2005 (SAFETEA) and its amendments, provided $90 million and authorized two demonstration projects, one east and one west of the Mississippi River.

The selected demonstration projects in Las Vegas, NV, and Pittsburgh, PA, never reached construction. SAFETEA funding for the Las Vegas maglev was redirected to a highway project; a Final Environmental Impact Statement was completed in 2010 before the Pennsylvania project was canceled as well. More recent appropriations for maglev research and development have not included the geographic distribution requirements contained in SAFETEA. Congress has appropriated a total of $14 million for maglev research and planning since FY2019.

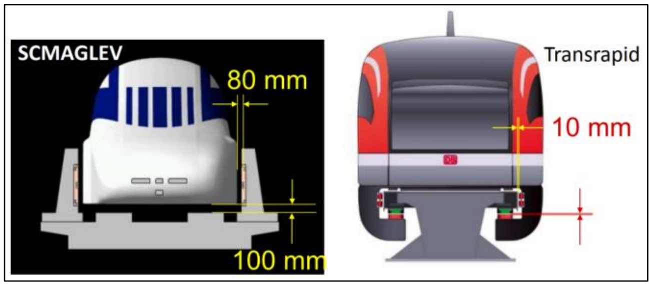
Competing Maglev Technologies

Transrapid, the first maglev system to be demonstrated, was developed in Germany, and uses what is known as electromagnetic suspension (EMS). Transrapid vehicles resemble monorails, using vehicles with sides that extend below and beneath a single central structure. Despite having pioneered the technology, Germany has not deployed its own maglev system for commercial use; a 25-mile line from Munich to its airport was canceled in 2008, mainly due to cost concerns. The Shanghai maglev opened in 2002 uses a version of the Transrapid design, and reaches a top speed of 268 miles per hour on its 18-mile trip to Pudong International Airport. Plans to expand the route into a 105-mile intercity line were suspended after a high-speed rail line, compatible with the rest of China's high-speed rail network, opened in 2010. China's proposed Hong Kong-Guangzhou line would use a different technology.

SCMaglev (short for superconducting maglev), developed in Japan, uses a technology known as electrodynamic suspension (EDS). SCMaglev trains run on guideways that more closely resemble trenches than monorails, and vehicles ride on a thicker cushion of air than in an EMS system (**Figure 1**). There is no SCMaglev line in revenue service anywhere in the world. However, a test track is operational in Yamanashi Prefecture, Japan, and is part of the Chuo Shinkansen project that would link Tokyo (though not its central rail station), Nagoya, and eventually Osaka on a new SCMaglev line built almost entirely in underground tunnels. This would create a faster and more direct alternative to a parallel high-speed rail line that is unable to accommodate new or faster traffic.

Figure 1. SCMaglev and Transrapid Comparison

Showing gaps between vehicles and guideways, in millimeters

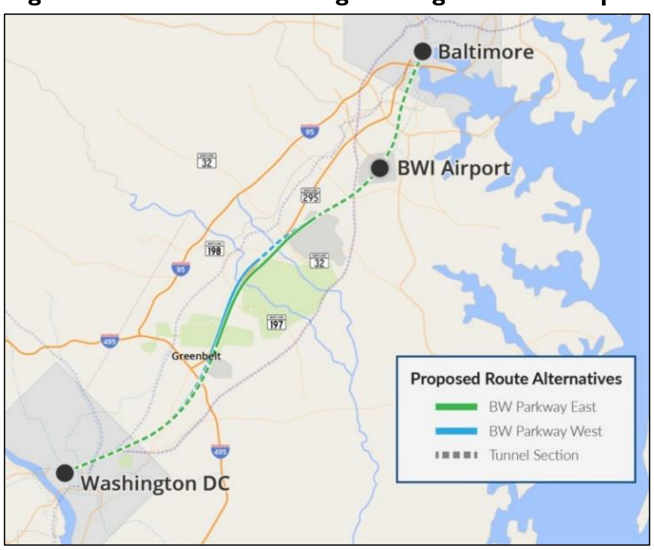


Source: Yoshiuki Kasai, "JR Central's Business Strategy," 2012, at http://icrier.org/pdf/yoshiyuki_Kasai.pdf.

Northeast Maglev Project Update

The primary recipient of federal maglev funds since the end of SAFETEA has been Northeast Maglev, a privately held company associated with the Central Japan Railway Company, the firm building the Chuo Shinkansen project. Northeast Maglev has proposed a line using SCMaglev technology linking Washington, DC, with New York City. The first 36 miles of the project would be built mostly in tunnels between Washington and Baltimore, MD, with a stop at BWI Thurgood Marshall International Airport in between (**Figure 2**). Northeast Maglev has advertised that the travel time on this leg would be 15 minutes, roughly a 45-minute improvement over a commuter train making local stops, and a 30-minute improvement over an Amtrak train making limited stops. Northeast Maglev has stated that half the cost of its project will be financed by the Japanese government, and that "the remainder of funding will come from U.S. government loan and grant programs, and the private sector."

Figure 2. Baltimore-Washington Maglev Route Map



Source: northeastmaglev.com.

A Draft Environmental Impact Statement (DEIS) for the project was published in January 2021. Capital costs for the alternatives considered in the DEIS ranged between $10 billion and $13 billion for the roughly 35-mile line, or $285 million to $370 million per mile. At that cost, the project would be much less expensive on a per-mile basis than other U.S. rail tunnel projects currently under construction or applying for construction funds. Exact comparisons are difficult since each project must contend with different topography and settlement patterns, but a four-track, two-mile rail tunnel also planned for Baltimore is expected to cost $4.5 billion, or over $2.2 billion per mile, albeit for twice as many tracks.

The DEIS cost estimates are in line with projected per-mile costs of building the 178-mile Chuo Shinkansen project, but there are few examples of U.S. public transportation projects involving extensive tunneling with per-mile costs similar to those in Japan; most are more expensive. The costs of building the Chuo Shinkansen itself may escalate as local opposition continues to delay the project.

Cost-Benefit Considerations

Other plans, some requiring federal support, could achieve more modest mobility improvements by less capital-intensive means. For example, a combination of faster-accelerating equipment, higher speed limits inside station approaches, and signal upgrades to allow closer spacing between trains could result in improved trip times and increased capacity on existing lines between Baltimore and Washington at a lower cost. While the time saved for riders from Baltimore to Washington would likely be much less than the 30 to 45 minutes estimated by Northeast Maglev, rail improvements would benefit travelers using intermediate stops, which a maglev line would not. Passenger fares on Amtrak (currently $20 to $50) or commuter rail ($8) would also be lower than tickets on maglev, estimated to cost between $27 and $80 per trip.

Some observers have asserted that while the Baltimore-Washington segment may not be well-suited for maglev, it is a necessary step toward the establishment of New York-Washington maglev service. There, too, it may be possible to improve speed and capacity of existing infrastructure to a point where investment in maglev may not be as attractive. Northeast Maglev envisions a trip of one hour between Washington and New York; the company has estimated that the full build-out to New York may cost upwards of $100 billion, with the configuration of a New York terminal and the need to tunnel beneath the Hudson River being major factors. Amtrak's plans envision a two-hour, 10-minute trip by conventional trains between Washington and New York; this would be over an hour longer than by maglev, but achievable with far less tunneling and with ancillary benefits to commuter and regional rail travel.

Nothing precludes federal support for conventional rail and maglev simultaneously within the same corridor; one justification for the Chuo Shinkansen project is that the parallel high-speed rail line offers a variety of service patterns and has little excess capacity. However, conditions are not yet as congested on much of the Northeast Corridor, including between Washington and Baltimore.

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