ANL/ES/CP--95537
CONF-980454--

Comparison Of High-Speed Rail and Maglev System Costs

By

Donald M. Rote
Argonne National Laboratory
9700 S. Cass Ave.
Argonne, IL 60439
Phone: 630 252 3786; Fax: 630 252 3443
don_rote@qmgate.anl.gov

Maglev '98 Hotel Highland Resort
Kawaguchi-Ko, Japan

April 12-16, 1998

Work supported by the U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy under contract W-31-109-ENG-38.

DISCLAIMER

Portions of this document may be illegible electronic image products. Images are produced from the best available original document.

Comparison Of High-Speed Rail And Maglev System Costs[1]

Rote, Donald M., Argonne National Laboratory,
9700 S. Cass Ave, Argonne, Illinois 60439, U. S. A.
Phone: 630 252 3786; Fax: 630 252 3443
don_rote@qmgate.anl.gov

Abstract

This paper compares the two modes of transportation, and notes important similarities and differences in the technologies and in how they can be implemented to their best advantage. Problems with making fair comparisons of the costs and benefits are discussed and cost breakdowns based on data reported in the literature are presented and discussed in detail. Cost data from proposed and actual construction projects around the world are summarized and discussed. Results from the National Maglev Initiative and the recently-published Commercial Feasibility Study are included in the discussion. Finally, estimates will be given of the expected cost differences between HSR and maglev systems implemented under simple and complex terrain conditions. The extent to which the added benefits of maglev technology offset the added costs is examined.

Introduction

Recent data show highway vehicles account for 86.5% of all passenger miles traveled in the U.S.. Aircraft account for 9.6% and commuter and Amtrak for 0.3% [1]. Consequently, it is easy to understand why public policy has not been supportive of investment in high-speed rail (HSR) or maglev technology. Nevertheless, it is becoming increasingly well recognized that it will not be possible to keep up with the growing demand for fast, efficient transportation by just increasing the capacity of the highway and air modes alone. A new mode of transportation, that is suited to U.S. demographics and that will encourage diversion from heavily-congested roadways and airways is clearly needed. Unfortunately, concern over the budget deficit and the growing cost of maintaining the existing transportation infrastructure. leaves little enthusiasm in political circles for public investment in new infrastructure. Even the national benefits of reduced congestion, and its concurrent reduction in energy use and emissions does not seem to generate much political interest. Shelton Jackson, in his personal perspectives on maglev technology (not speaking for the Administration) to the Maglev Study Advisory Committee, explained that congestion is a local and state problem, not a national problem [2]. On the other hand, it is noteworthy that, in recent years, there has been a gradual shift from Federal to State governments in control over how public transportation monies are spent. In addition, creative financing schemes are being developed that permit public-private partnerships to undertake new large infrastructure-based projects. This raises the prospect that entrepreneurs working together with local and state governments may be able to accomplish what has not been possible with the Federal government alone.

There is considerable confusion in the U.S. regarding the relative initial investments required for and benefits of proposed high speed rail (HSR) and maglev systems. Given the lack of real data, this is quite understandable. Unfortunately, rather than keeping an open mind until sufficient data is available, a strong bias against maglev and even to some extent against HSR has developed. It is based on a number of factors including the belief that higher speed is the only benefit maglev technology has to offer and that benefit does not generate enough additional ridership to justify its much greater cost. This impression has contributed to the dismissal of maglev technology as a viable mode of transportation, and prevented its further development in the U.S.. In order to correct this impression, it is necessary to clarify what maglev technology is, what benefits it can offer, why it is needed, and what its relative costs are. Obviously, because of the lack of actual cost data, it will be some time before this clarification can be completed. However, at this stage, it is important to make the case for maglev technology as clearly as possible, and attempt to present as accurate an estimate of the relative costs and benefits of HSR and this new mode of transportation as possible given present information. Presumably, this will also help to motivate better reporting of cost data and future efforts to reduce costs.

U.S. Federally-Sponsored Studies.

Three federally-sponsored studies involving maglev have been conducted recently: the Near-Term Applications of Maglev Technology; the National Maglev Initiative (NMI); and the Commercial Feasibility Study (CFS).

The Maglev Study Advisory Committee (MSAC) was established in December of 1996, by the Secretary of Transportation, to advise him in the preparation of a report to Congress on the "Near-Term Applications of Maglev Technology". Although the Secretary's final report has not yet been released, a status report in the form of a letter to the Secretary from the MSAC dated May 1, 1997 was distributed at the 1997 HSGTA meeting in Las Vegas [3]. That letter pointed out that a maglev system's operational flexibility and numerous technical attributes, and not merely its high speed, distinguished it as a new mode of surface transportation that meets the growing need for greater capacity and speed. In a subsequent statement the MSAC members requested that "near-term fiscal constraints not be

[1]Work sponsored by the U.S. Dept. of Transportation/Federal Railroad Administration, The U.S. Dept. of Energy, & Argonne National Laboratory.

allowed to prevent a complete evaluation of maglev, one that examines not only its near-term costs, but also its long-term benefits for the U.S. economy and quality of life in America." [4].

Both the NMI and the CFS tended to treat maglev vehicles as fast trains that were implemented according to more traditional railroad technology approaches. While some of the technical attributes, such as greater acceleration and deceleration and flexibility in route selection were recognized, maglev technology's complete range of benefits were not fully captured in the cost/benefit analyses. The NMI focused on the conceptual development of four American maglev concepts, and comparisons with the French TGV and German Transrapid System (TR07). A hypothetical composite of the four American design concepts was used to examine the costs and benefits of implementing such a system in a broad range of travel-demand markets represented by fifteen routes. Depending on the conservativeness of the assumptions, up to seven corridors were found to have revenue to cost ratios near to or greater than unity [5] & [6].

The CFS took a rather different approach and compared the relative costs and benefits of implementing a range of different ground transportation technologies in various corridors. The technologies ranged from low (90 mph) and moderate-speed diesel and electric trains (up to 150 mph) to high-speed rail (200 mph) and maglev (300 mph) [7]. Technologies with maximum speeds between 90 and 150 mph were referred to as "accelerail" options (e.g., "accelerail 90" meant 90 mph technology). Several important assumptions were made in the CFS that had significant impacts on the cost estimates:

1. For speeds up to 110 mph, at-grade crossings were permitted. 60 to 65% of all crossings required installing or upgrading flasher-gate systems and up to 10% required separation. For speeds between 111 and 125 mph, at-grade crossings required positive barriers against intrusion, and 25 to 30% of the crossings required separation. For speeds in access of 125 mph all crossings required separation

2. Both HSR and Maglev systems required all new rights of way, with the exception of some existing urban segments that were used by HSR. Accelerail 90 required no realignments outside of existing ROW's. Accelerail 110, 125, and 150 required modest realignments but no major construction or relocations. Accelerail options would receive the cooperation of the freight railroad companies that own most of the Nation's ROW's.

3. Large incremental infrastructure costs from 200 mph HSR to 300 mph maglev.

As the speed increases, assumption 1 caused a significant cost increase between 110 and 125 mph. Assumption 2 caused a very large increase in cost between the 125 and 150 mph options and the HSR and maglev options. A comparable very large increase in cost between HSR and Maglev was caused by assumption 3. The FRA is currently reexamining safety issues and this may alter assumption 1. (As an aside, it is worth noting that the speed limit on the interstate highway system, until recently, was 65 mph. That system did not permit any grade crossings). Assumption 2 is heavily dependent on cooperation of the freight railroads, which have expressed reluctance to cooperate because of possible interference with their freight operations which have an upper speed limit of 79 mph.

Several findings from the CFS are noteworthy:

1. The route lengths are the same for Maglev systems and HSR in all cases except the two California routes. This suggests that either the maglev technology offered no route alignment benefits for the other routes, or they were not taken advantage of.

2. The number of maglev vehicles per day is not consistently greater than the number of HSR trains, indicating that the potential benefits of small vehicle consists and high frequency service was not deemed to attract additional ridership.

3. The passenger*miles (PM) was greater, but not substantially greater than for HSR, despite the 50% greater top speed and substantially greater average speed. Even for the long routes where the speed difference is more important, the differences in PM were quite small.

4. In three of the cases studied, the differences, "U.S. Maglev"- HSR, in infrastructure initial investment per mile were substantially greater than what one might expect. These differences are: Cal N-S, $15.5 M/mi; Cal S, $11.9 M/mi; and Texas, $11.7 M/mi. It is not clear why these differences are so large. The absolute cost of the HSR system in the two California corridors, $27 M/mi., is well within the range expected for rights of way having significant portions not at grade. This implies that the maglev system costs should be roughly the same. The Texas corridor, by contrast, has a relatively low HSR cost, $10.1 M/mi., suggesting that most of its right of way is at grade, which would tend to maximize the cost difference. Even then, the $11.7 M/mi. cost difference still seems high except possibly for the TR07 vs. HSR system.

5. In only one case did the total cost per passenger mile for HSR exceed that for Maglev systems. This says that all of the attributes of the maglev technology did not attract a sufficiently greater number of passengers to compensate for the extra costs. -- A surprising result.

Basis of Comparison

In principle, a sound approach to comparing transportation investments should treat common features similarly and use deployment strategies, consistent with market characteristics, that capture the greatest overall benefits each technology has to offer.

HSR (maximum speeds greater than 125 mph) and maglev systems share several features in common. Both are guided ground transportation modes with very large capacity, and both use electric power from the utility grid for propulsion. (Options could be developed to carry primary energy sources on-board, but such options will not be considered here). Dedicated guideways/railways are generally required for best performance (especially in cases where mixtures of technologies having substantially different speeds and ROW requirements are involved) and grade-separated crossings must be provided for vehicular and pedestrian traffic, and animals. The ROW may be either at grade or separated by earthworks or concrete and steel structures depending on a variety of technology-independent considerations, but in any case, must be protected. Except for ground clearance requirements for the Transrapid system, there is no fundamental reason why HSR and maglev vehicles in general, could not both operate on either at-grade or elevated guideways. It would be inappropriate to assume, as is apparently sometimes done, that HSR systems can be constructed at grade while maglev systems must be constructed with elevated guideways. To be sure, the choice of elevated guideways could be advantageous for both HSR and maglev systems, but one system should not be required to adopt this costly option and not the other. Similarly, where reasonable, other common features should also be compared on an equal footing . For example, connections to the utility grid are required for both systems, and the costs should be accounted for in the same manner whether incorporated into the rate structure or regarded as capital costs. Another example involves the question of who pays for the required treatment of crossings?

HSR and maglev systems also exhibit some fundamental differences that distinguish them as very different transportation modes. Not only are the technologies employed quite different, e.g. steel-wheel-on-steel-rail vs. magnetic suspension, but so are the ways that they should be deployed and operated to capture all of their potential advantages. While the technical differences in the suspension and propulsion systems are generally recognized, the desired deployment and operating differences are not. To assume that maglev systems are merely very fast trains would not take advantage of all the attributes of that technology.

Maglev systems offer the unique combination of technical attributes of speed in excess of 300 mph, light weight vehicles, centralized and fully automated control of propulsion systems, non-reliance on adhesion for vehicle acceleration and braking forces, balanced three-phase loads on utilities, and the ability to operate with consists of as little as single cars carrying fifty to one hundred passengers without the need for highly-skilled operators. When compared with HSR, these technical attributes translate into higher acceleration and braking, greater curve and hill climbing ability, more effective use of regenerative as opposed to dynamic electrical braking, and lower staff and maintenance costs. In addition, the ability to use single or double-car consists economically, allows even relatively small markets to be given high frequency, reliable service.

In Japan and parts of Europe, where maglev technology can build upon strong cultural traditions of passenger rail use, and where travel corridors are very densely populated, the market characteristics warrant an approach toward maglev system deployment based on its speed, capacity and environmental attributes. Hence, it is appropriate to deploy maglev vehicles in long consists and operate them in a manner similar to that used for HSR. In the U.S., on the other hand, the situation is quite different. The lower population densities combined with the lack of a history of successful passenger-rail service suggests that simply increasing the speed alone will not generate the increased ridership needed to offset the added costs. Much shorter total trip times, together with frequent, highly reliable service, are required to attract new ridership and divert passengers away from their cars. In addition, it may be necessary to serve both intercity and commuter passengers on the same lines to help offset the infrastructure costs.

The combination of high acceleration and deceleration together with frequent service permitted by the use of short consists allows more urban/suburban stops to be made without significant increases in line-haul times. This, in turn, reduces passenger station access/egress times and eliminates the need for paasengers to arrive at terminals an hour or more in advance of scheduled departure times. It also allows both commuter and non-commuter service with the same system (off-line stops may be required on heavily-travelled lines). Combined together, these attributes allow passengers to save time on both short and long-haul trips. Consequently, it is reasonable to expect that if properly deployed and operated in U.S. markets, maglev technology would attract a significantly greater ridership and provide more benefits than would even 300 mph locomotive-drawn wheel-on-rail systems deployed in the traditional manner.

Maglev vs. HSR System Costs

For comparison purposes, it is often convenient to classify initial investment costs into three groups: infrastructure, rolling stock (vehicles), and other structures including stations, parking facilities, maintenance facilities, and other buildings. This classification is consistent with public/private financing plans adopted by some projects that have been proposed in the U. S. and for the Berlin to Hamburg Transrapid route in Germany.

Unfortunately, this classification scheme is not completely satisfactory for comparing maglev and HSR systems and can be somewhat misleading. Some cost items that fall under the infrastructure category in maglev systems are included in the rolling stock category in HSR. The power conditioning and the propulsion system components are good examples. They include transformers, rectifiers, inverters, and propulsion motor stator windings that are all part of the infrastructure in a maglev system but part of the locomotives in a HSR system. This difference between infrastructure-based and vehicle-based components makes maglev system infrastructure costs appear higher (of the order of $3 to 3.5 M/mi.) if only the infrastructure costs are considered. Combining the infrastructure and vehicle costs tends to alleviate this problem but introduces additional problems. The demand for vehicles depends on market conditions that change with time.

Hence, in high ridership markets, the higher maglev infrastructure costs are spread over more passengers. In addition, although the greater speed and accelerating capability means fewer vehicles are required to serve the same ridership as HSR, the total number of vehicles is likely to be significantly greater because of the expected much higher ridership. This complexity argues in favor of using cost per passenger mile in lieu of cost per mile for comparison purposes. It also indicates the need to use the present-value (based on some specified discount rate) of total life-cycle cost and benefit estimates.

Construction Cost Data

It should be understood that cost comparisons between HSR and maglev systems depend strongly on installation conditions and the specific technologies involved and, in any case, are quite uncertain. For convenience in the following, most costs have been converted to 1993 $ U.S.. This conversion includes use of in-country inflation factors to bring costs to 1993 values and conversion to U. S. dollars using 1993 currency exchange rates. Costs are generally for double-tracked systems.

Table 1. TGV Construction Costs in 1993 Dollars U. S.

Routes	Costs (M$/mi)	
Paris-Lyon	7.3	no tunnels
Atlantic	12.2	
North	13.7	
Paris Bypass	19.3	
Lyon-Valence	15	
Extension to Montpellier	21.5	
Madrid-Seville	9.7	2.1% elv., 3.4% tunnels

A breakdown of the TGV Atlantic cost estimate was given in [8]. Allowing for inflation from 1983 to 1993 (x 1.453), and converting to $ U.S. (5.67 FF = 1$ U.S.) and dividing by the length of the high-speed lines (174 mi), yields a conversion factor of 0.00147. The results are given below:

Table 2. Cost Breakdown for TGV Atlantic

Item	Cost in $M/mi (U.S.1993)
Land purchases, land reorganization, compensation	0.748
Preliminary work, earthworks, etc.	1.87
Structures	3.87
Road safety, fencing, sundries	0.135
Track & Ballasting	1.59
Telecommunications & safety installations	0.961
Electric traction installations	0.800
Buildings	0.722
Supplementary adaptations	0.863
Other	0.600
Total	12.15

The Atlantic system was built mostly at grade over flat and gently rolling countryside. For comparison purposes, the the first, fourth, and last three items are excluded yielding a net infrastructure cost of 12.15 - 3.07 = 9.08 $M/mi. How much would a maglev system cost for the same alignment? The Government Maglev System Assessment Team [9] concluded that a hypothetical U.S. maglev system built at-grade would have a "technology cost" of about 12.6 $M/mi, (1993 U.S.$). The "technology cost" excludes site work, fencing, high-voltage power distribution, markups, contingencies, and profits. These excluded items could significantly increase the price of a maglev system installation. The breakdown is given in Table 3.

Table 3. Estimated Technology Cost Breakdown ($ M/mi) for a hypothetical U. S. maglev system.

Item	@ Grade	Elevated
Guideway Structure	3.7	8.7
Guideway Magnetics	5.2	5.2
Guideway Power Dist.	0.6	0.6
Control & Commun.	1.4	1.4
Power Conditioning	2.0	2.0
Total	12.9	17.9

Comparing the data in Tables 2 & 3 shows that for the at-grade construction, maglev would cost at least 3.8 $M/ mi more than the TGV Atlantic. The cost difference may be significantly higher when actual costs are substituted for the maglev tchnology costs.

It is important to note that the difference between at-grade and elevated costs is significant. The cost penalty for elevating a HSR system is expected to be significantly higher due to the fact that the weight per seat is two to three times greater for HSR than for maglev vehicles. In addition, the cost of installing a catenary system increases when tunnels and bridges are involed. From Table 2 it is seen that the cost of the electric traction installations (catenary, supports, etc.) is about $0.8 M/mi. This can be compared with the contract received by Morrison Knudsen et al to design and install an electrification system over 157 miles between New Haven and Boston in 1992. The contract award was for $295.5 M or $1.88 M/mi for catenary, poles, foundations, traction power substations and switching stations. The substantially greater cost is due, at least in part, to the need to cross 253 bridges and accommodate many curves. Consequently, while at-grade maglev systems may be several $M/mi greater than HSR, this difference may be eliminated or even reversed for installations requiring elevated structures, bridges, tunnels, etc.

Table 4. Construction Costs for German ICE Systems

Route	Length of High-Speed Section (mi)	Cost ($M/mi,1993)
Hanover to Wurzburg	204.4	48
Mannheim to Stuttgart	61.9	50
Cologne-Frankfurt	135.0	32

The cost of more complex installations of HSR systems is illustrated by data in Table 4 on construction of German ICE high-speed lines [10]. These lines (Services speed = 156 mi/h, certified for 175 mi/h) are shared with slower 125 mi/h passenger trains and freight trains during the night.

Maximum axle loads are 19.5 tonnes (compared to 17 tonnes for the dedicated TGV lines in France). The Hanover to Wurzburg line is 56% at grade, 36% in tunnels, and 10% elevated structures. The Mannheim line is 65% at grade, 30% in tunnels, and 5% elevated structures. The tunnels required the design of special catenary support structures. The new 135-mi. high-speed line from Cologne to Frankfurt will have service speeds up to 188 mi/h.

Because of the numerous traffic routes, roads, motorways, railways, and waterways that have to be crossed, about 50% of the proposed Berlin-Hamburg Transrapid line will be elevated [11]. The guideway cost for the Transrapid system, is 5.6 BDM (1993 value) [11]. The cost for a 250-km/h HSR system was estimated to be about 5.5 BDM. It is noted that "The estimated costs for the construction of a TRANSRAPID route and the building of existing wheel-on-rail tracks are generally regarded as being somewhat the same." [11]. These estimates translate to 17.3 $M/mi and 17.7 $M/mi,for HSR and Transrapid, respectively.

The Shinkansen Series O system installed on the Tokyo-Osaka line in 1962 cost 217 MYen/mi. It was 33% elevated, 14% in tunnels. The Series 200 installed on the Tokyo-Morioka line cost 8770 MYen/mi in 1981. The Series 300 installed on the Omiya-Niigata line cost 7105 Myen/mi. in 1977. According to [12], "A Linear Express route can be constructed for about the same cost as that of existing bullet train routes. Construction costs are actually reduced because the Linear Express can run on extremely steep slopes and because it weighs only 30% to 50% of what the bullet train weighs. Also, because the Linear Express runs elevated from (i.e. above) the track, maintenance costs due to wear and tear are much lower than those for trains."

As noted in [13], because of the number of road crossings and urbanized areas along the routes in Japan, most high-speed lines would be elevated regardless of which technology is used. Elevated guideway costs probably are of the order of 2 to 3 BYen/km in Japan. Using a conversion rate of 122 Yen to the U.S. dollar, that is equivalent to about $26 to 39 M/mi..

Several early construction cost estimates based on proposed projects in the U. S. are summarized in Table 5. The selected route connecting Las Vegas to Southern California traversed the San Bernadino Mountains and the Mojave desert. It included a single track system with two 25-mile long passing loops. Two generic technologies were considered, a HSR system and a maglev system with maximum speeds of 185 mph and 250 mph, respectively. According to Barton-Aschman Associates, Inc. [14], an increase in average speed from 147 to 216 mph (47%) would yield an increase in ridership of 55%. Including a 12% contingency rate, the estimated capital costs for the period from 1987 to the end of 1994 would be $2.03 B and $2.53 B (in 1984 dollars) for the HSR and maglev systems, respectively [14]. These figures included the capital cost of the vehicles. On a per mile basis, these costs would be $11.9 M/mi and $14.9 M/mi in 1993 $. Taking into account the average speed differences, the ratio of the costs per passenger mile of the maglev to HSR systems would be 0.81. Hence, the increased ridership more than made up for the somewhat greater cost of the maglev system

Table 5. HSR and magiev system projects proposed in the U. S..

	Length (mi.)	Cost ($M/mi.) Maglev	HSR
Texas Triangle- Houston-Dallas-San Antonio	590		9.67 (1991)*
Florida: Pinellas Gateway to Orlando CBD via Orlando Airport	119		7.8**
Southern Cal.-Las Vegas	230	14.9	11.9***

* total cost, [15]
** track & structures only, [16]
*** single track & vehicles, [14].

More recently, The Florida Overland Express was awarded a franchise to develop a HSR system in Florida based on the TGV technology. The estimated total capital cost for the 320-mile system was $5.2 billion in 1995 dollars [17]. This translates into $15.5 M/mi in 1993 dollars.

Table 6. Present Value of Life-Cycle Costs and Benefits (1996 $ Billions)

	Basic System	Basic System + Extensions
Capital Costs		
VHSR	7.5	10.3
Magiev	10.6	14.5
Total Benef its		
VHSR	7.1	13.7
Magiev	10.6	19.5

A detailed cost and benefit analysis was recently completed for three generic technologies for the California Intercity High-Speed Rail Commission [18]. High-speed and very high-speed (>200mph) rail and Maglev systems were considered. Both a basic system (San Francisco to Los Angeles, 460 miles) and the basic system with extensions (total length 676 miles) were examined. The net present value of the costs and benefits for the period 2000 to 2050, assuming a 7% discount rate, are summarized in Table 6 for the VHSR and maglev systems. These results show that, in spite of the significantly greater costs for the maglev system, the greater benefits more than compensate for the added costs. It is worthwhile examining the results of this study in more detail to see where the large cost differences arise.

Table 7. Cost Ranges in 1995 $ For Selected Items For The California SR-99 Case.

Selected Items	VHSR	Maglev
Track & Guideway	570-691	2104-2122
Structures	1926-3336	2076-3548
Environmental Impact Mitigation	170-261	170-261
Signals & Comm.	281-294	550-575
Electrification	697-758	1970-2059
Vehicles	979	796
Route length (mi)	399.3-414.5	399.3-414.5

As shown in Table 7, the "Track & Guideway" and "Electrification" cost differences are about what one would expect, the "Structures" cost difference seems to have ignored the fact that the VHSR system is two to three times heavier than the Maglev system, and the "Environmental Impact Mitigation" item ignores the greater noise associated with the VHSR system in urban/suburban areas. Its not clear why the "Signal & Comm." item should be nearly twice as expensive for the maglev system, especially if the latter is operated in an automated mode without a conductor on board each train. Also note that the route lengths are the same, indicating that no account has been taken of the greater flexibility in alignment afforded by the non-adhesion based maglev system. It is also worth noting that the O&M costs (not shown above) were estimated to be the same for both technologies except for the energy costs which were slightly higher for the maglev system as expected. Evidently, the non-contact operation was of no net maintenance benefit.

Conclusions

If both HSR) and maglev systems are constructed at grade, the infrastructure cost of the maglev system would be expected to be several $M/mi greater for the hypothetical U.S. Maglev system. Technology advances could reduce these cost differences somewhat.

Part of the at-grade cost differences arise from technology-dependent tradeoffs between infrastructure- and vehicle-borne costs. For example, the major power conditioning and propulsion system components of the maglev system are part of the infrastructure, whereas for HSR those components are carried on board the locomotives. These components could account for a difference of the order of $3 to 3.5 M/mi.

To the extent that both HSR and maglev systems must be elevated, or extensive use of bridges and/or tunnels is required, the infrastructure initial investments are likely to be about the same. This is consistent with experience in Germany and Japan and with some, but not all, of the results of the CFS in the U.S.

For the CFS, the estimated difference in the ridership of the two technologies in the various study corridors does not appear to be consistent with expectations based on the comparative attributes of those technologies. This suggests that either the expectations were unwarranted or that the CFS methodology was insensitive to those technology attributes that, if capitalized on, would have shown better ridership. More detailed analyses are required to better understand why both the cost and ridership results of the CFS were not more consistent with expectations.

References

[1] Transportation Statistics Annual Report 1997, Bureau of Transportation Statistics 1997.

[2] Jackson, Shelton, Deputy Director, Office of Economics, U.S. Dept. of Transportation, comments to the Maglev Study Advisory Committee at its public meeting 2/6/98.

[3] Letter to The Honorable Rodney E. Slater, U.S. Dept. of Transportation from the Maglev Study Advisory Committee, May 1, 1997.

[4] Statement of the Maglev Study Advisory Committee, June, 1997.

[5] Final Report on The National Maglev Initiative, U.S. Dept. of Transportation, report no. DOT/FRA/NMI-93/03, Sept., 1993.

[6] Maglev For The United States, prepared by the U.S. Army Engineering Division, Huntsville, Al, August, 1993.

[7] High-Speed Ground Transportation For America, U.S. Dept. of Transportation, Sept., 1997.

[8] LeBoeuf, M. and A Palade. English translation of the complete Dec. 1986 issue of Revue Generale Des Chemins, page 137.

[9] Technical Assessment of Maglev System Concepts, Final report by the Government Maglev System Assessment Team, final draft, Oct. 1997.

[10] Burns, W. R., Germany's ICE Trains, Speedlines, page 9, Summer 1996.

[11] Personal communication from Mr. W. Mayer, Dornier SystemConsult, Dept. DCSV1, Friedrichshafen, Germany to D. M. Rote, Feb. 21,1997.

[12] Central Japan Railway brochure entitled "The Linear Express: Tomorrow's Transportation".

[13] Personal communication from Hiroshi Nakashima to Donald M. Rote, Feb. 14,1997.

[14] R. J. Harmon, & Assoc., Las Vegas To Southern California SS-GTS Phase II "Organizational/Financial" Analysis, prepared for the City of Las Vegas, March, 1987.

[15] MK-Led Consortium Wins 50-Year Franchise to Design, Build, Own, & Operate $5.7-Billion Texas High-Speed Rail System, News Release, Morrison Knudsen Corporation, May 28, 1991.

[16] "Florida Intercity Rail Passenger Service - Options for the 21st Century", Florida DOT, 1993.

[17] Smith, Charles, Director of the High-Speed Transportation Program, Florida DOT, presentation to the Maglev Study Advisory Committee on April 7,1997.

[18] High-Speed Rail Summary Report and Action Plan, Final Report, Prepared for the California Intercity High-Speed Rail Commission, Dec. 1996.