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HIGH-SPEED RAIL IN PENNSYLVANIA: CHANGES AND ADVANCEMENTS IN TECHNOLOGY, PASSENGER DEMAND FORECASTING, AND FINANCING ALTERNATIVES SINCE THE MID-1980S

Prepared for

Commonwealth of Pennsylvania
Department of Transportation and
the Mid-Atlantic Universities Transportation Center

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13. ABSTRACT *(Maximum 200 words)*

The present study attempts to serve high-speed rail interests in Pennsylvania by addressing three specific HSR-related issues: (1) changes in HSR technology since approximately the mid-1980s, (2) advancements in intercity passenger demand forecasting since the mid-1980s, and (3) capital financing alternatives for HSR systems. A fourth issue, recent developments in HSR technology on the Northeast Corridor (NEC) of the United States, is also briefly addressed. With respect to financing alternatives for HSR systems, the present study examines financial options grouped by financing sources for capital costs, funding sources for capital costs, and revenue sources for operating costs. There is a brief discussion of the TEA 21 Innovative Financing provisions. There is also a discussion of issues surrounding private sources of financing, including options for using a mixture of private and public-sector financing that varies by stage of project development. Regarding passenger demand forecasting for HSR, the discussion is concerned with advances that have been made in intercity travel demand forecasting since the mid-1980s. The discussion focuses on three topics: theoretical understanding of trip-making behavior; modeling techniques; and data availability, collection, and presentation.

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Executive Summary

In late 1981, the Commonwealth of Pennsylvania authorized the creation of an independent commission for the purpose of conducting a high-speed passenger rail feasibility study for the Pittsburgh-Philadelphia corridor. The Pennsylvania High Speed Rail Commission (PHSRC) was subsequently formed to address this issue.

The PHSRC's technical consultants conducted their work over the period of August 1983 to July 1987. Further technical work was suspended at that time when public funding support was terminated. Consequently, the consultants were not able to complete their study of several key issues, including a final assessment of economic impact, a detailed financing plan, an engineering plan, right-of-way alignment revisions designed to reduce costs, or an assessment of a proposal by Transrapid International for a magnetic levitation rail system in a portion of the corridor.

While a cessation of funding ended the PHSRC's technical work, there nonetheless has continued to be an interest in high-speed rail (HSR) for Pennsylvania. The present study attempts to serve that interest by addressing three specific HSR-related issues: (1) changes in HSR technology since approximately the mid-1980s, (2) advancements in intercity passenger demand forecasting since the mid-1980s, and (3) capital financing alternatives for HSR systems. A fourth issue, recent developments in HSR technology on the Northeast Corridor (NEC) of the United States, is also briefly addressed.

Regarding changes in HSR technology, the present study first examines the technologies considered by the PHSRC and then discusses advancements that have been made. The main conclusion is that while there have been advancements in HSR technologies over the last decade, available information indicates that the changes have not been of a magnitude that would produce great leaps in HSR performance. Some incremental improvements have been made in the maximum speeds attainable using different technologies. Existing technical and speed characteristics of three groups of HSR systems categorized by speed are presented, including a comparison of electromagnetic suspension systems and electrodynamic suspension systems. Some advantages and disadvantages of maglev in comparison to steel-wheel on steel-rail are also presented.

Also discussed is the National Maglev Initiative (NMI), which identified some promising innovations that, if proven effective in operation, would deliver improved performance or reduced cost. However, the recommendations of NMI regarding a research program and development of maglev technology indigenously has to date not been pursued by the U.S. government. Thus the performance and cost impacts from some of these promising innovations can only be contemplated at this time.

Regarding safety, the main issue is the amount of safety provisions that are required. In Europe, policy has evolved whereby a dedicated track for passenger operations alone does not require safety provisions of the kind required where freight traffic has to coexist. This is not the case in the United States, where the options are either modify the Code of Federal Regulations totally for exclusive high-speed operations and bring them in line with the Union of International Railways standards, or devise new standards. Revising the standards would seem to make the most sense in light of the fact that the same systems have run efficiently in Europe with an excellent safety record and that the import of technology and rolling stock would therefore prove less expensive for the U.S. market.

With respect to financing alternatives for HSR systems, the present study gives a summary of the financing options that were explored in the PHSRC report as well as a discussion of the issues surrounding the financing options. It then details more recent financing options available, grouped by financing sources for capital costs, funding sources for capital costs, and revenue sources for operating costs. Finally, there is a brief discussion of the TEA 21 Innovative Financing provisions.

Additional information, contained in the appendix, includes HSR development experiences of California, Texas, Florida, Europe, and Amtrak, as well as a listing of what is available on the Federal Railroad Administration Internet web site. As of December 1998, it appears that Florida has surged ahead of all other U.S. states in terms of its commitment to high-speed rail on dedicated lines; the state has programmed $70 million in transportation trust fund monies for 40 years to be used for debt service on revenue bonds that are expected to be issued to finance a portion of the capital construction costs. In 1996, the state selected the Florida Overland eXpress (FOX) group to design, build, and operate a dedicated high-speed rail line between Miami and Tampa, via Orlando. Florida will own the infrastructure, and FOX will purchase and operate the trains while paying the state a fee for use of the infrastructure. The financing plan, presented in the appendix, proposes federal, state, and private sources. A commitment for the federal share had not been obtained as of December 1998.

The current study also presents a discussion of issues surrounding private sources of financing. The advantages of greater private-sector involvement in public-use transportation projects have been well documented. They include the profit motive as a lever to build and operate more efficiently and with higher quality and customer satisfaction. In the case of large-scale transportation project development, the advantages are argued to also include fewer project-approval burdens and the absence of government procurement constraints. At least in the United States, experience is showing that the cost of financing is not one of the advantages of private financing sources for large-scale, capital-intensive transportation projects because private-sector sources of financing are more expensive than public sources. That is, for a given transportation project, the private sector's cost of capital, assuming the absence of tax-exempt debt, exceeds the public sector's cost of capital.

Some of the barriers to attracting private-sector financial participation in HSR projects, whether by equity investors or by commercial lenders, include the tendency of existing HSR operations to operate at a financial loss, the likelihood of project development/implementation delays and cost overruns, the cumbersome nature and expense of the project development and implementation process itself, and the threat of competitive emerging technologies. To address these financing challenges, some have suggested dividing the development and implementation process into phases that are financed separately using mixes, that may vary by phase, of public and private-sector sources.

One approach argues that the early phases of project development, including all activities associated with clearing a project, involve the most uncertainty and therefore are the riskiest and least attractive to potential private financing sources. The approach also argues that the public sector is best suited to the early project development activities, such as right-of-way acquisition and environmental clearances. Once a project has achieved all its clearances, the uncertainty about project timing, scope, and costs is significantly reduced, making the remaining phases of project development/implementation and operation much more attractive to potential private-sector financial participation.

Another financing plan suggests more of a mixture of private and public-sector financing through most phases of HSR project development. Like the first approach, this plan anticipates the largest financial role for the private sector to be the financing of the HSR operating system. It also foresees the private sector financing at least a portion of HSR fixed facilities provided tax-exempt revenue bonds are available for this purpose. Due to federal legislation passed in the early 1990s, HSR now appears exempt from the tax-exempt public debt limitations set by the Reagan Administration's Tax Reform Act.

This approach also sees potential to capture private financial participation in early project development phases by reducing risk through government guarantees; these guarantees are designed to protect at least some of the private financing if the project does not move to completion. The approach agrees that right-of-way acquisition is primarily a public responsibility, but argues that at least some of this cost can be recouped through various value-capturing techniques, recognizing that such techniques are highly dependent upon local government authorization and cooperation.

Others are critical of plans to attract private capital for financing early project development phases due to the magnitude of the financial returns required, especially when there are attractive, less-expensive alternatives. They suggest revolving-loan fund concepts, such as the U.S. DOT's state infrastructure bank program that is financed through state grants, taxes, or bond proceeds. Another alternative is governmental forms of credit enhancement that can help to reduce debt coverage ratio requirements. In either case, the project benefits from lower costs of capital due to the government's tax-exempt status. Furthermore, the benefits of private-sector participation can be realized without private capital investment in these early phases.

Regarding passenger demand forecasting for HSR, the discussion is concerned with advances that have been made in intercity travel demand forecasting since the completion of the PHSRC study in the mid-1980s. The discussion focuses on three topics: theoretical understanding of trip-making behavior; modeling techniques; and data availability, collection, and presentation. Before addressing these items, an overview of travel demand forecasting is given, followed by a brief review of the forecasting efforts of the PHSRC.

A major shortcoming and the principal handicap for the PHSRC forecasting efforts was the lack of good base-year data. The modeling approach itself, specifically the mode-split model, was very close to if not state-of-the-art for intercity demand modeling in the mid-1980s. However, there have been some significant advances in intercity demand modeling since that time. With regard to knowledge of trip-making behavior, for example, an activity-based framework is replacing a trip-based approach, thus enabling forecasters to address directly and more accurately those issues that influence the generation of trips. There is also 15 years more experience with the leading modeling techniques, thus much more is known about how to use the techniques properly to produce more stable estimates. Also, new techniques, such as microsimulation with stochastic, activity analysis approaches are producing better, more stable model parameters, although applications have been primarily limited to urban area as opposed to intercity forecasting.

Nonetheless, as the lack of good travel data severely constrained the quality of the demand forecasting efforts of the PHSRC, unless new data collection efforts are undertaken, then any future forecasting efforts for HSR in Pennsylvania will be similarly inhibited. The types of data needed are presented in this report. Some of these data and the newer modeling techniques they support must be obtained through smaller, but more focused collection methods conducted over time, in contrast to the massive, one-time data collection efforts characteristic of most feasibility studies conducted in the 1980s and earlier.

One issue that was beyond the scope of this report is the question of why the many HSR efforts in North America have not moved beyond the feasibility study phase other than on the Northeast Corridor. Several political scientists commenting on this question believe that the most difficult barriers to HSR development and implementation are not technical or financial, but are political and organizational in nature.[1] They believe that the efforts thus far have failed to craft a sufficiently strong and durable policy network across a broad enough institutional constituency to sustain the effort to fruition. They base their opinions on observations of HSR development in other parts of the world, the development of federal and state programs to support highways and urban mass transit in the United States, and numerous aborted HSR efforts in North America. The authors of this report believe there is significant wisdom in and much to be learned from these observations.

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[1]See Dunn, James A. Jr. and Anthony Perl, "Building the Political Infrastructure for High Speed Rail in North America," Transportation Quarterly, Vol 50, No. 1, Winter 1996, pp 5-22.

1. Introduction

In late 1981, the Commonwealth of Pennsylvania authorized the creation of an independent commission for the purpose of conducting a high-speed passenger rail feasibility study for the Pittsburgh-Philadelphia corridor. The Pennsylvania High Speed Rail Commission (PHSRC) was formed and charged with examining the following (*1*):

- Need and demand for high-speed rail (HSR)[2] passenger service,
- Construction costs and available technologies,
- Possible location and extent of specific routes to be served,
- Economic impacts of construction and operation,
- Financing options, and
- Local issues.

The commission's technical consultants conducted their work over the period August 1983-July 1987. Further technical work was suspended when public funding support was terminated. Consequently, the consultants were not able to complete their study of several key issues, including a final assessment of economic impact, a detailed financing plan, an engineering plan, right-of-way alignment revisions designed to reduce costs, or an assessment of a proposal by Transrapid International for a magnetic levitation rail system in a portion of the corridor.

While a cessation of funding ended the commission's technical work, there nonetheless has continued to be interest in high-speed rail for Pennsylvania. This work attempts to serve that interest by addressing three specific HSR-related issues:

1. Changes in HSR technology since approximately the mid-1980s,

2. Financing alternatives for HSR systems, and

3. Advancements in intercity passenger demand forecasting since the mid-1980s.

A fourth issue, recent developments in HSR technology on the Northeast Corridor (NEC) of the United States, is also briefly addressed.

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[2]In this report, high-speed rail (HSR) includes magnetic levitation systems as well as steel wheel on steel rail systems capable of operating for sustained periods at speeds of at least 242 km/h (150 mi/h).

2. Changes in HSR Technology

This section begins with a description of the technologies considered by the PHSRC and their corresponding performance characteristics as estimated by the PHSRC. This description is followed by a discussion on advancements in HSR technologies during the 1990s.

Technologies Examined and Recommended by the PHSRC

The PHSRC used the following attributes to define HSR systems (*1*):

- Passenger trains sustaining a minimum operating speed of 201 km/h (125 mi/h), and as high as 403 km/h (250 mi/h).
- New trackage dedicated exclusively to high-speed service, including grade-separated highway and pedestrian crossings. Trains would also not operate on freight trackage.
- On-board services, such as computer-communication systems and amenities superior to those offered by conventional rail service or airlines, including characteristics of interior roominess and constraint-free surroundings.
- Clean, efficient, appealing, and for the most part centrally located stations that offer ticketing, baggage service, and easy connections to other transportation modes.
- Large parking facilities at stations to encourage the use of the automobile as a feeder mode for intercity trips.
- A commitment to regular, orderly maintenance of trains, trackage, signals, and stations to maintain the system's reliability and performance.

Two principal capital cost components of a HSR system are the rolling stock and the right-of-way alignment. The commission initially considered the rolling stock technologies given in table 1 and the five alignment alternatives shown in table 2. The technologies presented in table 1 may be roughly grouped into the following three categories, with right-of-way requirements as described.

Maglev. Maglev systems are automated, fixed-guideway ground transportation systems capable of moving passengers at very high speeds (over 403 km/h [250 mi/h]). Forces of attraction or repulsion caused by magnets located in the vehicle are used, depending on whether the system is one of electromagnetic suspension (EMS) or electrodynamic suspension (EDS). A linear electric motor propels the vehicle forward. However, as the vehicles themselves contain no active drive elements, they can be particularly light. Also, as there is no contact between the vehicle and the guideway, there are few moving parts, less friction and wear, and potentially less maintenance and noise than with steel-wheel on steel-rail systems.

High-Speed Steel-Wheel Service. Specially designed lightweight train-sets equipped with high-power electric locomotives run on dedicated, grade-separated track with limited curvatures and modest grades. The track conforms to very high geometric and structural design standards. Signaling and communication equipment are fully automatic. This system utilizes rolling stock of the French TGV and German ICE type.

Table 1. Rolling stock technologies initially explored by the PHSRC.

1. The German Maglev system, promoted by Transrapid International, which had achieved 357 km/h (222 mi/h) during test runs using the TR-06 vehicle at the test track in Elmsland, Germany.

2. The Japanese MLU-001 (maglev) that had achieved 403 km/h (250 mi/h) during test runs by the Japanese Railways at Miyazaki, Japan.

3. The French TGV, then operating at 270 km/h (168 mi/h).

4. The German ICE, already tested at 406 km/h (252 mi/h) and commissioned into service at 250 km/h (155 mi/h) shortly thereafter.

5. The Japanese Shinkansen, or Bullet Train, which started in 1964 at a commercial speed of 209 km/h (130 mi/h) and had since been upgraded on some lines to 242 km/h (150 mi/h).

6. Three systems then being developed to approach or exceed speeds of 242 km/h (150 mi/h): the Italian State Railways proposed ETR 500 for speeds of 301 km/h (187 mi/h) and the ETR 450 "active tilt" train for 250 km/h (155 mi/h); and the British "Electra" locomotive operated at 225 km/h (140 mi/h).

7. British HST, or Inter-City 125, a diesel-powered train that had been tested at 238 km/h (148 mi/h).

8. Spanish Talgo Pendular, a diesel or electric powered "passive tilting" coach system.

9. Amtrak AEM-7 locomotive/Amfleet coach combination available at a speed of 201 km/h (125 mi/h) on the North East Corridor.

10. Swedish X2 with "active tilting" mechanism for travel at 201 km/h (125 mi/h).

11. Turbotrain for non-electrified territory where it provided service, under varying conditions as in France, Egypt and the United States (outside the Northeast Corridor) ranging up to 177 km/h (110 mi/h).

12. The Canadian LRC "active tilt" system as operated on VIA Rail.

Table 2. Alignment/general technology options considered in Phase I by the PHSRC.

1. Existing alignment – conventional rail

Passenger services assumed to operate by sharing track with freight services. Curves, grades, grade crossings, etc. preclude high-speed running. Similar to Amtrak services outside the Northeast Corridor.

2. Existing alignment – improved rail

Roadbed assumed to be rebuilt to higher standards of track geometry, signal and communication systems upgraded, and certain other constraints relaxed. Sharing of right- of-way with freight services assumed, but passenger services, either diesel or electrically powered, assume a higher ratio of horsepower per ton of weight. In places where curvatures found excessive, use of tilting train services explored to enable trains to negotiate curves at faster speeds while meeting requisite passenger comfort standards (keeping centrifugal forces experienced by passengers under tolerable limits). Similar to Amtrak's Northeast Corridor service.

3. Straightened existing – improved rail

Existing alignment serving population centers directly and realignment being resorted to in cases where the curves are overly restrictive. Freight trains not assumed to run on the same track except under emergencies. Exemplified by French National Railway's Paris – Lyon service using the TGV.

4. New alignment – advanced rail

When less costly options do not fulfil performance requirements or when line suitable for high-speed operation simply does not exist. There also may be regional development objectives that become possible to be fulfilled under drastically reduced travel times that can be achieved under this option. The track is fully dedicated to high-speed passenger operations. The New Tokaido Line that reduced travel time from 6.5 hours to 3 hours 10 minutes between Tokyo and Osaka in 1964 is representative of this alignment.

5. New alignment – levitated system (maglev)

An exclusive guideway for very-high-speed passenger operations (greater than 403 km/h [250 mi/h]). Non-contacting vehicles' travel suspended, guided, and propelled above the guideway by magnetic fields. Permits even faster speeds than advanced rail mentioned previously. But requirement of serving population centers necessitates use of existing right-of-way that limits speed at entry/exit from urban centers. Not tried commercially.

Moderate-Speed Steel-Wheel Service. A low-cost alignment would utilize rolling stock of either the TGV-ICE type or of the LRC, Turbo, Talgo, X2, or Amfleet type. Tilting trains permit a speed of about 20 percent higher at curves than is otherwise possible without causing undue discomfort to passengers facing centrifugal forces. Speeds up to 242 km/h (150 mi/h) are in the range of reckoning.

These three categories, in essence, constitute the three recommended options, in decreasing order of preference, presented in the PHSRC's final report (*1*). They represent a cost-service continuum, with the maglev option holding down the higher capital cost, higher service performance end of the continuum. The following describes each option in terms of the PHSRC's estimated initial capital expenditure, speed, and travel times.

Option 1 (Maglev Service) was estimated to cost $10 billion for a double–guideway system. It was expected to cover the 507-km (315-mi) distance between Pittsburgh and Philadelphia in about 2 hours at a maximum speed of 403 km/h (250 mi/h) with en route stops at Greensburg, Johnstown, Altoona, Harrisburg, Lancaster, and Paoli. The average speed, including station stops, is calculated at approximately 251 km/h (156 mi/h).

An alternative alignment suggested by Transrapid International, covering only the portion from Pittsburgh to Harrisburg (with the remainder to be served by French TGV or German ICE type operation), envisaged a single guideway, no tunneling, two passing double-tracks of 40 km (25 mi) each and a transit time of 1 hour 28 minutes. This proposal included a connection to State College and Lewistown as well as stops in Greensburg, Johnstown, and Altoona. Including station stops, the calculated average speed is 291 km/h (181 mi/h). The proposed alignment without tunneling promised to reduce transit time and to lower initial capital costs relative to Option 1. The capital cost was estimated at $3 billion (*1*).

Option 2 (High-Speed, High-Tech, Steel-Wheel Service) was estimated to cost $7 billion. Travel time was estimated at 2 hours 41 minutes, including stops. Maximum running speed was assumed to be 290 km/h (180 mi/h) with an average speed of 189 km/h (117 mi/h). It should be noted that the original Paris-Lyon TGV line operated at a maximum speed of 270 km/h (168 mi/h) and averaged 214 km/h (133 mi/h). In other words, the average speed estimated for Pennsylvania was lower, even though the maximum speed was higher than in the case of the original French TGV. This is indicative of some of the terrain challenges found in Pennsylvania and the concomitant impact on travel times. It should also be noted that the commission's final report indicated some criticism by suppliers and engineers familiar with TGV costs in Europe that the commission's cost estimate was too high.

Option 3 (Moderate-Speed, Steel-Wheel Service) was estimated to cost $2.55 billion and to cover the distance from Pittsburgh to Philadelphia in 3 hours and 43 minutes at a maximum speed of 241 km/h (150 mi/h) as against normal transit time of about 7 hours. It would utilize a passenger-dedicated track within much of the existing rail alignment, as only 81 km (50 mi) of realignment was contemplated. The distance of this alignment is 547 km (340 mi); thus the average speed for the journey, including stops, is just over 147 km/h (91 mi/h). The existing alignment was built to accommodate movement of heavy freight trains through mountainous terrain of central and western Pennsylvania. Thus the route is more circuitous than those envisioned for Options 1 and 2, and the rolling stock/alignment combination is not capable of reducing transit times as significantly as those two options.

Technological Advancements

While there have been advancements in HSR technologies over the last decade, available information indicates that the changes have not been of a magnitude that would produce great leaps in HSR performance. Some incremental improvements have been made in the maximum speeds attainable using different technologies. Thus, TGV-type operations are already running at 299 km/h (186 mi/h) in Europe, and speeds in the range of 354 km/h (220 mi/h) now look more achievable (a speed of 518 km/h [322 mi/h] was achieved during test conditions on May 18, 1990). Similarly, tilting-train technologies have developed further than what was viewed in the mid-1980s as the upper limit of 242 km/h (150 mi/h). Speeds of 300 km/h (186 mi/h) for commercial service now look possible (*2*).

Tables 3 through 5 present some of the existing technical and speed characteristics of three groups of HSR systems categorized by speed, as summarized by Eastham (*2*). The groups approximately correspond to the maglev, high-speed steel-wheel, and moderate-speed steel-wheel categories presented earlier. Both of the systems in table 3 are tilt-body systems whose advantage is their ability to operate at moderately high speeds on existing alignments while the train body tilts to prevent passengers from experiencing uncomfortable lateral accelerations. The ABB X-2000, designed and built by Asea Brown Boveri (ABB), operates on the Swedish State Railways. Its first revenue operation was in 1990 between Stockholm and Gothenborg. The X2000 trainset was tested on the United States Northeast Corridor at speeds up to 225 km/h (140 mi/h) during the spring of 1993.

The Fiat ETR-460 is a second-generation system designed and built by Fiat Ferroviaria and operated on the Italian State Railways. The first generation ETR-450 was introduced into revenue service between Florence and Rome in 1988, operating at a maximum speed of 250 km/h (155 mi/h). The maximum speed on this second generation trainset is 300 km/h (186 mi/h).

Each of the three systems in table 4 operates primarily on dedicated, special-purpose rights-of-way designed with limited curvature. Advanced technology applications, such as microelectronics in controllers and signaling, power electronics and devices in propulsion equipment, advanced materials in car body construction and aerodynamic vehicle shaping continue to be researched, experimented, demonstrated, and implemented in these systems (*2*). The TGV is built by a consortium headed by GEC-Alsthom and operated by SNCF. Revenue service opened in 1981 between Paris and Lyon and operated at a top speed of 270 km/h (168 mi/h). The newer TGV-Atlantique using the TGV-A trainset initiated service between Paris-Tours-Lemans in 1989 at a top speed of 300 km/h (186 mi/h). The same trainset design is used on the Paris-Lille line that just recently extended service to Brussels, also operating at a top speed of 300 km/h (186 mi/h). These are currently the fastest revenue train services in the world. A specially equipped and shortened TGV-A trainset has been tested at 515.3 km/h (320.1 mi/h) (*2*).

Table 3. Features of 250 km/h (155 mi/h) tilt-body trains.

Characteristic	*ABB X-2000*	*Fiat ETR-460*
In commercial service	1990	1994
Top speed	276 km/h (171 mi/h)	300 km/h (186 mi/h)
Service speed	210 km/h (130 mi/h)	250 km/h (155 mi/h)
Vehicle type	locomotive-hauled with driving trailer	EMU
Consist	1.4 DT (in service)	M-T-M-M-T-M-M-T-M (9 cars)
Seating capacity	200 (all 1st class); 254 mixed	456 + 2 disabled
Propulsion	ac 3-phase asynchronous; 815 kW; 4 powered axles	dc; 500 kW, body-mounted; 12 powered axles/train
Braking	Blended regenerative, discs, magnetic rail brake	Blended rheostatic and discs
Power supply	OCS 15 kV, 16 2/3 Hz single phase	OCS 3 kV dc
Axle load	18.25 tonnes (max.)	12.5 tonnes
Unsprung mass	1.8 tonnes/axle	1.6 tonnes/axle
Maximum tilt	8°	8°
Other features	Steerable powered trucks	Partially active lateral suspension

Source: Thomas Lynch, *High Speed Rail in the U.S. Super Trains for the Millennium,* Gordon and Breach Science Publishers, 1998.

Table 4. Features of high-speed transit with 300 km/h (186 mi/h) capability.

Characteristic	*TGV-Atlantique*	*ICE-1*	*Series 300 (Nozomi)*
In commercial service	1989	1991	1992
Top speed	515.3 km/h (320.1 mi/h)	406.9 km/h (252.7 mi/h)	325.7 km/h (202.3 mi/h)
Service speed	300 km/h (186 mi/h)	250 km/h (155 mi/h); 280 km/h (174 mi/h) on some truck segments	270 km/h (168 mi/h)
Vehicle type	Articulated trainset	Loco-hauled	EMU
Consist	1.10-1	1.13-1 or 1.14-1	16:5 (M-T-M) and cab car
Seating capacity	369 coach; 116 first	681 (1.14-1)	1,323
Propulsion	ac synchronous, 1100 kW, 8 axles powered	ac asynchronous, 1200 kW, 8 axles powered	ac asynchronous, 300 kW 40 axles powered
Braking	Blended rheostatic, disc and tread brakes	Blended regenerative and discs	Blended regenerative, disc and eddy-current
Power supply	OCS 2 x 25 kV, 50Hz	OCS 15 kV, 16 2/3 Hz	OCS 2 x 25 kV 60Hz
Axle load	17 tonnes	20 tonnes	11.3 tonnes
Unsprung mass/axle	2.2 tonnes	1.87 tonnes	1.86 tonnes

Source: Thomas Lynch, *High Speed Rail in the U.S. Super Trains for the Millennium,* Gordon and Breach Science Publishers, 1998.

A consortium led by Siemans designed and built the German Intercity Express (ICE). ICE is operated on the German Federal Railways. Commercial service commenced between Hannover and Wurzburg in 1991. Top speeds can reach 280 km/h (174 mi/h) (*2*).

The third system shown in table 4 is the Japanese Shinkansen, which initiated service in 1964 between Tokyo and Osaka. Numerous additional lines have been built since. Current operating speeds are limited to 270 km/h (168 mi/h) by noise and vibration concerns expressed in the communities through which the trains pass, and by alignment geometry. The newer Series 300 equipment shown in table 4 has been tested at a maximum speed of 325 km/h (202 mi/h). It entered revenue service in 1992.

Table 5 presents characteristics of the two maglev-based technology systems, the German Transrapid and the Japanese Linear Express. Based on the published literature, these systems currently are by far the two most advanced systems in terms of their technological development. However, neither system is in commercial operation; current expectations are that one or both will be in commercial service in the middle to late years of the first decade in the 21st century. Based on tests conducted thus far, revenue service of 325-350 km/h (202-217 mi/h) appears technically feasible and achievable while speeds of 400-500 km/h (248-311 mi/h) remain the target (*2*).

The foundation of maglev technology rests in fundamental physical science principles associated with electricity, magnetism, and propulsion. Maglev trains are designed to float on a magnetic field established within a guideway, in contrast to conventional ground transport systems that ride on wheels in contact with the way. The system that levitates a maglev train is separate from the system that propels the train along the guideway. One of the principal differences between the Transrapid and the Linear Express maglev systems is the different levitation technologies they employ. The Japanese levitate by repulsion, using electrodynamic suspension. The repulsive force is generated between superconductive magnets carried in the vehicles and aluminum coils mounted in the guideway (*2*). The vehicle coils sit above the track coils and the direction of currents created in the coils is such that there is sufficient repulsive force generated to overcome gravitational forces associated with the weight of the train to essentially push the vehicle away from the track (*3*). The magnets and coils are superconductive to provide for lower resistances, which allows more current to be generated with less power, making the induced magnetic field stronger (*4*).

Table 5. Features of superspeed MAGLEV systems.

Characteristics	*EMS System Transrapid*	*EDS System JR Linear Express*
Country of origin	Germany	Japan
Status	Pre-deployment testing	Development testing
Geometry	Up to 10% gradient, 5800m radius curve	Up to 4% gradient, 8000m radius curve
Guideway	2.8m wide, simply-supported guideway, steel or concrete	2.8m U-shaped concrete guideway, simply supported
Power supply	20kV, 3-phase VVVF to windings in guideway	VVVF inverters feeding windings in guideway
Control and communications	Unique ATC/ATO with moving block; VHF vehicle-wayside communications	Under development, but similar in principle to that used by Transrapid
Key guideway features	Guideway carriers windings for iron-core LSM guidance rails, waveguide. Required alignment tolerances +/- 0.6mm for stator packs	Guideway alignment tolerances are less critical than for EMS system due to larger air gap [100-150 mm vs. 8-10 mm]; air-core LSM
Vehicle type	Articulated EMU	Articulated EMU
Dimensions (1 x w x h)	25.5m x 3.7m x 3.95m	21.6m x 2.8m x 2.85m
Consist size standard	2, 4, or 6	14
Capacity standard	200, 400, 600	988
Propulsion	Iron-core LSM	Air-core LSM
Braking	LSM thrust reversal; eddy-current emergency brakes	LSM thrust reversal; aerodynamic emergency brakes; aircraft discs on undercarriage wheels
Guidance	Non-contact magnetic attraction	Non-contact magnetic repulsion
Body structure	Aluminum alloy	Aluminum alloy
Suspension	Magnetic primary; pneumatic secondary	Magnetic primary; spring secondary
Axle load	1.6 tonnes/m	1.0 tonnes/m
Design speed	400-500 km/h (248-311 mi/h)	500 km/h (311 mi/h)
Hotel power collection	Non-contact linear generator	Non-contact linear generator
Noise level	84-86 dB(A)	N.A.
Key operational features	Propulsion, braking are not adhesion-limited	Larger air gap; inherently stable suspension; faster

Source: Thomas Lynch, *High Speed Rail in the U.S. Super Trains for the Millennium*, Gordon and Breach Science Publishers, 1998.

The Germans levitate by attraction, using electromagnetic suspension. In this system, a portion of the vehicle containing iron-cored electromagnet coils wraps around the track such that the coils are under ferromagnetic components in the guideway. The direction of the currents is established such that the two coils are attracted to each other. As a result of the attraction, the portion of the vehicle sitting above the guideway is pushed away from the track (*3*). EMS is inherently unstable because the attraction forces become stronger as the gap (roughly 9.5 mm [3/8 in]) closes. This means that advanced control systems are needed to ensure the gap is continuously monitored and that power supply is adjusted to keep the gap at constant levels. The small size of the gap requires that construction of the guideway be done to very precise tolerances (+/- 2 mm [0.08 in]) (*4, 5*).

The EDS system, in contrast, is stable because the repulsive forces that keep the vehicle away from the guideway become stronger as the suspension gap decreases. Guideway clearance on EDS systems is 100-150 mm (3.94-5.91 in.) at high speeds (*2*). EDS vehicles, however, require wheels, as magnetic levitation is speed dependent, being low at low speeds. The wheels are retracted as the vehicle reaches a speed of roughly 97 km/h (60 mi/h). The EMS systems do not have this requirement, as the suspension gap is nearly speed independent (*5*).

Linear synchronous motors (LSM) are used by both the Transrapid and Linear Express propulsion systems. The Japanese system uses air-cored LSMs, while the German system uses iron-cored LSMs (*2*). Both also employ magnetic guidance systems that generate strong magnetic forces to control lateral displacements within the guideway. The Linear Express guidance system is mounted on each side of the guideway. The Transrapid system has electromagnets in the vehicles that interact with ferromagnetic rails on the sides of the guideway (*2*).

The Japanese have constructed the Yamanashi Maglev Test Line for the purpose of full-scale maglev operational testing. Among the matters to be tested are required minimum curve radii and maximum gradients. The test line is designed with a minimum radius of curvature of 8,000 m (8,753 yd) and a maximum gradient of 4 percent. Two train sets will be operated on the line to test a 550 km/h (342 mi/h) maximum run. One 18.4-km (11.4-mi) section of the test track will be a double track where it will be possible to study the dynamics of trains passing each other at a relative speed of 1,000 km/h (621 mi/h). Eighty percent of this section is tunneled. According to the Railway Technical Research Institute (RTRI), which operates the test facility, the following milestones have been achieved (*6*):

- October 3, 1997 - Manned maglev vehicle "MLX01" attained 451 km/h (280 mi/h) at Yamanashi Test Line.
- December 12, 1997 - Maglev vehicle "MLX01" attained 531 km/h (330 mi/h) at Yamanashi Test Line.
- December 24, 1997 - Maglev vehicle "MLX01" attained 550 km/h (342 mi/h) (the goal maximum speed) at Yamanashi Test Line.

One focus of RTRI research is superconducting magnet (SCM) reliability and durability. SCMs can lose their magnetomotive force due to external magnetic disturbances caused by the ground coils and from mechanical vibrations caused by vehicle dynamics. RTRI states it has developed countermeasures for this problem, although it does not provide details. Some other areas of RTRI development include aerodynamic brakes using panels on car roofs and disc brakes, sidewall levitation ground coils, and a high-power supply system for pulse width modulation (PWM) inverters using gate turn-off (GTO) thyristers (*6*).

The Germans also have a full-scale test facility at Emsland, constructed in the early 1980s, where vehicles are tested and demonstrated under close-to-operational conditions (*2*). A pre-production vehicle, the Transrapid TR-07, built by Thyssen Transrapid System, has been under testing at this facility since 1988. The Transrapid technology has been selected by the German government for implementation on a new line between Hamburg and Berlin. This route is 292 km (181 mi) in length and is anticipated to have five stops, including the terminal stations. Travel time is expected to be 1 hour maximum, meaning the average speed will be 292 km/h (181 mi/h).

In late 1991, an independent German review board declared the Transrapid "technically ready for service" (*7*). The board's review covered the overall system and all subsidiary subsystems and components, including:

- The vehicle,
- The support and guidance systems,
- The drive and power supply,
- The operational control and communications systems, and
- The guideway and its points.

Review criteria included function, reliability, availability, safety, controllability, flexibility, margin for errors, serviceability, environmental compatibility, system compatibility, and comfort (*8*).

The "technically ready for service" designation means that "there are no system or safety risks, neither at the level of the overall system nor any of the subsidiary systems, that the investment costs can be predicted with sufficient accuracy, and that the necessary planning and approval procedures can be initiated" (*8*). The next steps in the development program focus on improving the economic efficiency of subassemblies and subsidiary systems of the vehicle, the drive, the guideway, the operational controls, and the operating facilities while also improving the environmental compatibility of the overall system. All systems will have to be certified at the Emsland test track and confirmed to be ready for production before the German Federal Railways Office will grant approval to operate the Transrapid train in commercial passenger service on the Berlin-Hamburg route.

The next generation Transrapid vehicle, the Transrapid 08, was to begin testing in late 1998. Improvements have been made in reducing weight and enhancing aerodynamics, which will make these vehicles quieter and more energy efficient. Key data on this vehicle follow (*9*).

Transrapid 08 Technical Data:

Vehicle length	79.70 m (87.2 yd)
Vehicle width	3.70 m (4.0 yd)
Seats	60 (1st class, middle section)
Total weight	188.50 metric tons
Payload	39 metric tons (according to system specification)
Design speed	550 km/h (342 mi/h)
Operating speed	0-500 km/h (0-311 mi/h)

Some Advantages and Disadvantages of Maglev

Some advantages of maglev in comparison to steel-wheel on steel-rail railways include (*4, 10*):

- Low wear and maintenance expense: Wear and tear from contact stresses are very low because there are few contact points. Maglev trains have mostly electromechanical and electronic components instead of mechanical parts.

- Energy efficiency: Maglevs appear to be only slightly better in energy efficiency than steel-wheel-on-rail systems because there is no wheel-on-rail friction. However, the vast majority of resistive force at high speed is air resistance for which maglev has no inherent advantage over conventional rail systems. On the other hand, in comparison to air transport, maglev is considerably more energy efficient.

- Speed: Maglev's traditional advantage over steel wheel on rail trains has been speed, but the magnitude of its advantage may be shrinking. In the 1960s, it was customarily believed that the maximum practical speed limit for steel-wheel-on-rail trains was in the neighborhood of 250 km/h (155 mi/h), while maglev's maximum speed was in the range of 450-500 km/h (280-311 mi/h). Technological advances in steel-wheel-on-rail systems has pushed actual operating speeds to 300 km/h (186 mi/h) and 350 km/h (217 mi/h) looks technically and operationally feasible (*2*).

The use of superconducting magnets to levitate and propel maglev trains creates one of the current principal technical disadvantages of maglev. Most magnets used in maglevs are made of NbTi. In operation, these magnets get very hot and must be cooled down to 4°K to maintain their properties. Liquid helium is the cooling agent generally used. As it absorbs the heat of the magnets, the helium liquid turns to vapor. The difficulties arise in trying to store the helium vapor and reliquify it. Cryorefrigeration techniques that constantly cool the magnet without flashing the helium appear most promising but very expensive (*4*). More research is needed not only to improve cooling systems but to possibly design cooler superconducting magnets.

National Maglev Initiative

In early 1990, several U.S. federal agencies formed the National Maglev Initiative (NMI) for the purpose, in part, of conducting research and evaluation of the applicability to high-speed ground transport of several advanced technologies (cryogenics, high-temperature superconductivity, power electronics, and aerodynamics) from industries such as aerospace (*2*). Part of this effort was also to evaluate claims regarding opportunities for technological improvements relative to maglev systems under development in Germany and Japan. In short, NMI found some of these claims to be justified while others appear to have been overstated. Following are the significant findings from the NMI effort taken directly from its final report. Note that references to "existing" capabilities are as of approximately 1993 (*11*).

> A U.S. 300-mi/h (500-km/h) maglev system is feasible. U.S. industry and academia have the capability to compete with foreign maglev developments. Assessment of the four conceptual designs elicited from U.S. firms concludes there are many areas where improvements can be made with systems more suited to U.S. geography and demographics.
>
> Tilting mechanisms have been designed for maglev vehicles that allow them to follow existing ROW at speeds substantially higher than the design speed of existing maglev technologies. In those cases where land is unavailable or too costly, this will provide an acceptable alternative route.
>
> In connection with the above finding, it has also been established by experiment that most people do not suffer ill effects from the large tilt angles and rates of turn involved in following existing ROW at high speed.
>
> Magnetic fields created by a maglev system can be attenuated to normal urban levels without severe weight or cost penalties. Measurements of magnetic fields aboard existing transportation systems reveal that fields substantially in excess of ambient occur in and around certain electrically powered systems, just as is the case with many home and office appliances. However, the steady magnetic fields measured aboard the Transrapid Maglev vehicle are no greater than the earth's field. Although the magnetic fields generated by superconducting magnets are greater than the Transrapid values, design approaches exist to maintain the fields in the passenger compartment to acceptable levels.
>
> Procedures have been identified for the use of new composite materials and innovative vehicle and component designs, which can reduce the weight of maglev vehicles and energy consumption. In addition, the application of sophisticated manufacturing and erection techniques to guideway construction may greatly reduce the transportation and site preparation costs associated with building in or near existing ROW.
>
> Overcoming aerodynamic drag on vehicles is the dominant factor in energy consumption at 483 km/h (300 mi/h). Research shows there are ways of reducing drag which provide a fruitful area for additional research.

Maglev systems can offer significant energy savings relative to air and auto when configured in multiple-car consists due to less than the proportional increase in aerodynamic drag. However, there appears to be no energy advantage for single or dual car consists.

Maglev has the potential for being quieter than conventional trains at speeds below 155 mph (69 m/s), which is an important consideration when traveling in urban areas where speed restrictions will most likely be in place. At speeds above 155 mph (69 m/s), most of the noise produced by a vehicle is of aereodynamic origin, whether it is on rail or levitated. As in other transportation modes, methods exist to alleviate noise where necessary.

The power semiconductors that are required to regulate the propulsion currents in the guideway will require improvements in the state of the art, particularly in regard to bringing costs down. U.S. manufacturers are in a favorable position to accomplish this and improve their market position with respect to allied products as well.

Developments in high-temperature superconductors have made such progress in the past 2 years that it is prudent to consider designs for superconducting magnets and cryostats that incorporate this new technology. Avoiding very low temperatures would reduce complexity, weight, and operating and maintenance costs for cryogenic systems.

Innovative operational strategies, such as single-car, nonstop, point-to-point service, can provide faster travel between suburban stations, making the maglev system more competitive relative to the automobile.

Maglev systems can take advantage of existing infrastructure to provide access to city centers and intermodal facilities. In many cities, existing bridges, tunnels, and transportation corridors are not being used to full capacity and could be inexpensively modified to accommodate maglev. Techniques exist for coupling maglev vehicles to, or mounting them on, rail vehicles to provide near-term access to rail terminals until maglev facilities can be built in these congested areas.

The large air gaps made possible with superconducting magnets do not appear to lead to any significant guideway cost savings compared to small-gap EMS systems. Ride quality, rather than gap control, is the significant factor in setting guideway precision and rigidity requirements. However, large air gaps do enhance the safety of the system by increasing the tolerance to nondesign irregularities arising from damage, earthquakes, or improper maintenance.

In order to take full advantage of a large air gap, a suspension with sophisticated characteristics, such as some combination of feedback, preview, and adaptive control, is needed. Such a suspension may allow lower guideway fabrication and maintenance tolerances, consequently reducing associated costs. While the current concept designs are capable of traversing a single large perturbation of guideway geometry, these suspensions cannot traverse repeated guideway irregularities and offer a comfortable ride. Research to determine the optimum suspension force-control characteristic is ongoing.

NMI also identified some promising innovations which, if proved effective in operation, would deliver improved performance or reduced cost. These innovations included:

The individual control and activation of each guideway propulsion coil for the linear synchronous motor LSM, known as local commutation, was once regarded as impractical. Millions of silicon switching devices would be required for an intercity route, but if the trend of reduced costs with volume applies here, as it has with other semiconductor devices, the LCLSM will lower cost while enhancing propulsion performance. Research is in progress to further assess this concept, which could provide an important strategic advantage for American competitiveness in semiconductor technology.

A spinoff of the locally commutated LSM is the capability to use the same coil system to transfer auxiliary (hotel) power from the guideway onto the vehicle, with an attendant reduction in on-board battery requirements. The advantage is reduced vehicle weight and improved safety.

Applying the rapid advances in power semiconductor technology, in which the United States has a lead, will enable substantial reductions in size, weight, and cost. Also, improvement in the efficiencies of power conditioning equipment for both vehicle and wayside systems will be provided.

Some of the design concepts allow maglev vehicles to make use of completely electronic switches (turnouts). These switches have no moving parts and, therefore, could substantially reduce the costs of achieving the tolerances required for rapid activation. Higher vehicle speeds through the switch and reduced headways improve trip time and increase system capacity.

Novel helical winding designs for LSM may allow operation at higher voltages with improved electrical efficiency, better power factor, and no component and installation cost penalty.

However, the recommendations of NMI regarding a research program and development of maglev technology indigenously has to date not been pursued by the U.S. government. Thus the performance and cost impacts from some of these promising innovations can only be contemplated at this time.

Safety

As with any transport system, traveller and public safety is of prime concern. The Transportation Research Board's publication, *In Pursuit of Speed*, states the following regarding needed maglev safety research and testing (*5*):

> .....the following key safety concerns that must be addressed before maglev systems can be operated in the United States: fire safety; vehicle crashworthiness; on-board battery supply reliability; suspension system failure at high speeds; hovering reliability; emergency preparedness, including emergency evacuation, enhanced emergency braking and stopping, lightning protection, and earthquake impact; air quality in the passenger cabin during emergency conditions; and fail-safe mechanical guideway switching. Standards must also be established for managing the electronic fields associated with maglev operation to minimize the effects on human health and system electronics and local telephone, radio, and television reception.

The U.S. DOT's recent HSR commercial feasibility report continues the same theme while linking the impact of safety research and regulation to the capital cost structure for HSR systems (*12*).

> In the design and application of all HSGT technologies, the Department regards safety as paramount. Evolving safety research and regulation could thus influence the capital cost structure for Accelerail (for accelerated rail service), New HSR, and Maglev.

The PHSRC final report recognized the outstanding safety record of existing HSR operations, noting that the bullet trains of Japan, since their inception in 1964, had maintained an accident-free record of carrying over 3 billion passengers without a single fatality and that the French TGV maintained a similar perfect record since initiation of its full operation in 1983. These safety records remain largely unchanged today.

One of the important reasons the PHSRC gave its highest recommendations to a dedicated track without any grade crossings and away from freight railroad right-of-way was to ensure high levels of safety with maximum emphasis on collision avoidance. The maglev system is seen as derail proof as the vehicles wrap around the guideway and thus there is no possibility of a derailment. They are also collision proof as successive sections are powered only as the vehicle moves over it and the sections behind and ahead have no power. Automatic signaling and communications are a major component of all high-speed options and they work to enhance safety.

With regard to the issue of safety regulation, the Union of International Railways (UIC) standards applicable in Europe have a different historical background than the Code of Federal Regulations (CFR) applicable in the United States. The U.S. systems assumed freight operation along with passenger operations on the same or adjoining trackage. In Europe, however, because of governmental support, policy evolved whereby passenger operations became a distinct entity in their own right. A dedicated track for passenger operations alone did not require safety provisions of the kind required where freight traffic had to coexist. The emphasis in Europe has been on collision avoidance, whereas in the United States it has been on collision avoidance and also (as track had to be shared with freight trains) on collision survivability. Thus rolling stock can be lighter in Europe with lower buff strengths than in the United States (220 T [200 Mg]) versus 400 T [363 Mg]).[3] This is a design advantage due to the intricate relationship between lighter trainsets and their capability for higher speeds.

The option before the United States is to either modify the CFR regulations totally for exclusive high-speed operations and bring them in line with the UIC standards, or to devise new standards. Revising the standards would make sense in light of the fact that the same systems have run efficiently in Europe with an excellent safety record and that the import of technology and rolling stock would therefore prove less expensive for the U.S. market. If the standards are not revised, the costs of importing technology would be greater, as the systems would have to be redesigned for the U.S. standards. And, as heavier trainsets are fairly incompatible with higher speeds, there may be a need for further research and development as well. For example, even if heavier trainsets can be made to potentially achieve speeds comparable to their European counterparts, the problem of braking shall remain. Thus investment in braking R&D would be needed that would take time and resources.

This issue was raised in the TRB publication, *In Pursuit of Speed*, but the same has yet to be reconciled (*5*). In the meantime, waivers have to be obtained from the FRA for operating at speeds in excess of 177 km/h (110 mi/h), on a case by case basis, and the North East Corridor has thus had to obtain the requisite waiver to run trains at 242 km/h (150 mi/h) for the service scheduled to start from October 1999. And with regard to maglev, new standards still have to be developed for this mode, which has yet to be introduced into revenue anywhere in the world.

With reference to the maglev technologies of EMS and EDS, some basic differences in the technologies produce variation in stability and wheel requirements, as discussed previously.

It may also be mentioned that the Transrapid's maglev does not include detection devices for foreign objects on the guideway. The system relies on elevated guideways to restrict access and near-grade guideways that are protected by fencing (*5*).

Whereas technological improvement requires research and development effort, certain factors have since come into play that will have a bearing on the financial viability of high-speed projects and hold potential to significantly alter the "bottom line." These factors essentially provide for a more even "playing field" between high-speed ground transportation (HSGT) and what were, until now, the more favored modes (i.e., highway and air). The measures are:

- Lifting of tax restrictions on high-speed bonds in the Internal Revenue Code (*7*).
- Providing for federal guarantees for high-speed loans up to $1 billion (*7*). These have been further safeguarded in the Transportation Equity Act for the 21st century (TEA-21).

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[3]Buff strength refers to the rail car structure's ability to withstand longitudinal forces applied at a point behind the coupler. Some believe that the number of fatalities and injuries would have been less, although not zero, if U.S. standards had been in place in the June 3, 1998 HSR German accident (News, National Association of Railroad Passengers, Sept. 1998).

- ISTEA provision permitting maglev systems to be built on federal highway rights-of-way without any charge for such access at the state's discretion (*7*, *13*).

These and related capital financing matters are addressed in the next section of this report.

3. Financing Alternatives for HSR Systems

This section presents a compilation of financing-related material from varied sources. It begins with a summary of the financing options that were explored in the PHSRC report as well as a discussion of the issues surrounding financing options. It then details more recent financing options available, grouped by financing sources for capital costs, funding sources for capital costs, and revenue sources for operating costs. Finally, there is a brief discussion of the TEA 21 Innovative Financing provisions.

Additional information, contained in the appendix, includes the experiences of California, Texas, Florida, Europe, and Amtrak, as well as a listing of what is available on the Federal Railroad Administration Internet web site.

Overview of Financing Options Examined by the PHSRC

This overview is not a complete rendition of all that is contained in the financing section of the Interim Report, but is meant to simply give a summary of the main ideas related in the area of possible financing options. In addition, funding for the PHSRC project was discontinued before a detailed financing study could be completed.

Table 6. Proposed systems costs and revenues.

	Maglev	VHS	Conv. Rail	Transrapid
First operating year	2000	1998	1993	
Construction cost estimate ($1986)	$10.311B	$6.998B	$2.55B	$2.9-3.0B
Total revenues ($1986)	$224M	$190M	$145M	
O&M costs ($1986)	$104M	$105M	$98M	
Margin for debt service ($1986)	$120M	$85M	$47M	
Margin for debt service	$238M ($2000)	$153M ($1998)	$68M ($1994)	
Annual debt service	$1.97B ($2000)	$1.34B ($1998)	$323M ($1994)	
Annual deficit	$1.732B ($2000)	$1.255B ($1998)	$276M ($1994)	

Table 6 presents the three proposed systems in the Interim Report and associated costs and revenues for each. All the systems were estimated to generate revenues in excess of operating costs, but not sufficient enough to meet the annual debt service. It is not clear, however, whether the debt service estimate includes debt financing costs other than interest.

Methods to maximize potential financing by minimizing the fixed costs associated with high-speed rail development are explored. These costs can be minimized by either obtaining the maximum equity investment possible and/or borrowing money at favorable rates.

Possible equity investment sources suggested include:

- Sales of stock to the public or in private placements;
- Investments made through limited partnerships;
- Acceptance of an ownership interest in the project by vendors and suppliers as partial payment for capital items sold;
- Grants from public bodies;
- Donation of assets by public bodies or private sources; and
- Other capital contributions made by groups benefitting from the project, such as property owners, hotels, theme park operators, and others.

Possible ways of obtaining favorable interest rates include:

- Borrowing at preferential rates from vendors,
- Using tax exempt debt, and
- Obtaining loan guarantees from public or private sources.

Specific ways to obtain equity investments and favorable interest rates discussed more thoroughly include the following.

Vendor Participation

Vendor participation includes basically any method used by a good or service producer to aid a potential purchaser to finance an acquisition. Vendors are interested in these methods to try to make sales that otherwise may not have occurred. This type of financing is attractive to vendors when they may be trying to enter into a new market, such as high-speed rail, and demonstrate their product. Several examples of vendor participation projects in the past are given, and in particular, suggestions that could be applied in Pennsylvania include:

- Acceptance of stock in the HSR portion of the equipment purchase price,
- Lease/purchase or equipment trust financing on favorable terms,
- Credit guarantees from vendors or financial institutions associated with vendors for debt issued by the HSR venture, and
- Substantial discount of the purchase price to cut initial investment requirements.

Tax Benefits

The Interim Report itself does not enter into an in-depth discussion of federal tax law, but points out that potential investors could be lured into the HSR program through the tax benefits of depreciation, investment tax credits (ITCs), and initial deductions for net operating losses

(NOLs). Certain lease arrangements can allow investors who are seeking tax shelter to basically purchase the benefits from entities that do not need these shelters. These organizations include private companies with little taxable income or public agencies.

Value Capture and Land Development

The construction of a HSR system would most likely have the benefit of increased property values along its route, especially at its stations. Therefore, both private and public owners of the system could utilize a financing component that makes use of these increased real estate values in order to either reduce the initial costs of capital or help contribute to operating revenues. These value-capture arrangements could be a significant portion of the financing of the venture.

Tax-Exempt Revenue Financing

Tax-exempt revenue financing basically enables a private organization to finance a capital investment with bonds whose interest is not subject to federal income tax. At the time the Interim Report was prepared, some changes were being made to current legislation that could impact this type of financing. (This is discussed further in a section titled "Financing High-Speed Rail," on p. 27.)

Grants and Subsidies

The authors of the Interim Report believe that because of the significant benefits the Pennsylvania economy would realize from the HSR system, there is a powerful case for public financing of at least part of the project. Several options include direct grants, credit support, donation of land, and provision of parking facilities in order to publicly subsidize some construction costs.

Adjustments in Project Scope

An interesting analogy can be made between the barriers to financing HSR in Pennsylvania and those that were present with the beginning of the railroad industry (i.e., "the technology was new, markets were untested, the equipment had limited liquidity, large initial investments were needed, and fixed costs were high"). In order to try to attract investors, in certain cases, governments may change the scope of the project by granting land or other tangible assets.

There are several ways changing the project scope may be advantageous in reducing costs. These include improvements to adjacent freight lines, conveying additional assets or development rights, and multiple use of rights-of-way. However, there may also be some disadvantages associated with each of these, and these should be carefully considered.

Potential Financing Package

A complete hypothetical financing package was proposed containing these elements:

- A public/private sector approach,
- Maximum use of ITCs and NOLs,
- Vendor support through loan guarantees,
- Favorable interest and repayment terms, and
- Public-sector financial support through favorable loan terms.

Discussion

The early 1980s saw a historic surge in initiatives worldwide to privatize assets and services traditionally developed, owned, and operated by governments. Such efforts continued through the 1980s and 1990s, although refined in scope based on experience gained from earlier periods. Transportation assets and services, including roads, airports, and railways, are among the more popular items to gain the attention of privatization experiments.

The advantages of greater private-sector involvement in public use transportation projects have been well documented. They include the profit motive as a lever to build and operate more efficiently and with higher quality and customer satisfaction. In the case of developing large-scale transportation projects, the advantages are argued to also include fewer project approval burdens and the absence of government procurement constraints.

Original visions for privatizing large-scale public use transportation projects contained images of projects financed largely from the private sector, which would be attracted by the revenue stream generated from payments made by users of the project. Such optimism can be found in the history of early 1980s HSR initiatives in Florida (see appendix). However, at least in the United States, experience is showing that financing is not one of the advantages of privatization for large-scale, capital-intensive transportation projects because private-sector sources of financing are more expensive than public sources. That is, for a given transportation project, the private sector's cost of capital, assuming the absence of tax-exempt debt, exceeds the public sector's cost of capital (*14*).

Unfortunately for those attempting to develop transportation infrastructure, there does not appear to be an untapped pot of inexpensive private-sector financing waiting to be invested in public use transportation projects. The two best known attempts to privately finance such projects in the United States are the SR 91 Toll Road in California and the Dulles Greenway Toll Road in Virginia. In both cases, the private capital raised is being repaid by users of the facilities, and the cost to those users is higher than it would have been had the project been financed through tax-exempt government sources. The private sources of capital did not provide any funds that could not have been raised from public sources and at lower cost (*14*).

Financing High-Speed Rail

Few observers today would disagree with the position that the development and implementation of HSR systems requires a mix of public and private-sector financing sources. However, attracting private capital to HSR projects is a significant challenge. Many of the difficulties stem from the sheer magnitude of the required financing coupled with great uncertainties or risks that make HSR projects relatively unattractive for most private-sector investors or lenders. Some of the barriers to private-sector financial participation in HSR projects, whether by equity investors or by commercial lenders, include the following:

- The tendency of HSR operations to operate at a loss: Experience with existing HSR operations in Europe, Japan, and on the U.S. Northeast Corridor indicates that in general, these operations do not cover their operating costs, with the possible exception of a few segments. Also, new transportation technologies historically tend to offer either service or user cost advantages over existing forms of transport. While there may be some substance to this argument, HSR is generally not perceived as offering such advantages relative to existing transport alternatives. There is enough skepticism about how HSR services would fare in competition with existing modes to make the private sector reluctant to invest in HSR.

- The likelihood of project delays and cost overruns: Large-scale, public-sector transportation projects tend to experience significant delays and costs that exceed budgets. If such a project has been financed with debt, a repayment schedule will have been established; the delays and cost overruns may jeopardize that schedule, raising the possibility of default (*15*). To counteract the higher risk associated with this prospect, the private sector will seek more attractive returns, such as higher interest rates or a government guarantee that payments will be made as scheduled. It may also be necessary to increase the size of the project contingency fund. Either of these items, the higher rates, government guarantee, or larger contingency funds, raise total project capital costs.

- Project development and implementation process: The scale of HSR projects is such that numerous clearances and permits are required from many different public agencies. Examples include an environmental impact statement, local zoning, conservation commission, and historic preservation clearances. Obtaining the clearances requires long public review processes and the expenditure of significant financial resources, all of which must be done far in advance of receipt of any revenues that might flow from the project. Furthermore, the findings of the environmental impact statement might cancel the project or add significantly to project capital costs. These uncertainties, the magnitude of up-front costs, and the long time period before revenues are generated are particularly unattractive to equity investors and make it difficult to get their participation in the early phases of project development (*15, 16*).

- Emerging new technologies: Another factor creating more uncertainty for HSR is the possibility that new forms of communication technology, such as desktop videoconferencing, may reduce the need, or at least the growth rate, for intercity travel. The uncertain degree to which these technologies will substitute for intercity trips versus increasing the number of visual interactions further exacerbates the risk of HSR investment.

To address these financing challenges, some have suggested dividing the development and implementation process into phases that are financed separately using mixes of public and private-sector sources that vary by phase (*15, 16, 17*). The principal project development and implementation phases are:

- Identify the basic corridor.
- Determine project feasibility and basic design: this includes initial environmental analysis, ridership and revenue forecasts, preliminary engineering, cost estimation, financing/funding plan and implementation plan.
- Complete project development: this includes all necessary actions to clear the project for construction, including assembling the right-of-way, completing the preliminary design, and satisfying environmental requirements, clearances and permitting.
- Complete final design.
- Develop project financing.
- Perform project construction.
- Initiate project operation.

Fielding and Klein recommend that the public sector be responsible for financing the first three phases of the development/implementation process, including all the activities associated with clearing the project (*17*). In their view, the public sector is positioned to assemble right-of-way and to steer a project through the myriad of public review processes at a lower cost than the private sector. Once a project is cleared, there is considerably less uncertainty about environmental requirements and other project costs, including the up-front administrative costs required to obtain all the necessary clearances and permits. This makes the remaining phases of the project development/implementation process much more attractive to the private sector.

Fielding and Klein suggest that a competitive bidding process be used to award a franchise to the winning bidder to complete the four remaining phases of the process. Revenues from project operations are then dedicated to repayment for the expenses incurred in these phases and to providing an adequate return on investment (*17*).

Allen's approach is somewhat different (*16*). He stresses more of a mixture of private and public-sector involvement in several phases of the process. While recognizing that project feasibility is the highest risk phase in the process for the private sector, he nonetheless sees an opportunity to attract private-sector equity to fund this phase if the public sector guarantees partial or full repayment, should the project not move to completion due to political, environmental, or public benefit/cost reasons. If the project is completed, then the equity position is repaid from operating revenues (*16*).

Allen views the acquisition of right-of-way as primarily a public responsibility, although there is the opportunity to reduce these costs through subsequent revenue streams generated by various value-capturing techniques. The implementation of such techniques is highly dependent upon local government cooperation and authorization.

Allen divides the financing of the fixed facilities, which is everything from the top of the operating surface down, from the operating system itself, which consists of vehicles, power system, fare collection system, signaling and communications systems, and so on. He views the financing of the fixed facilities to be a government responsibility, with the primary funds coming from dedicated transportation infrastructure funds. At the time of his writing, such funds did not exist; today they do exist in very limited form at the federal level and in some states such as Florida. Even their availability in limited form, however, helps to make other sources of financing more feasible.

Another source of fixed facilities financing suggested by Allen is project revenue bonds secured by fixed grants that would help to lower interest costs. He argues that such bonds should be tax-exempt and should not be subject to the state caps on tax-exempt financing imposed by the Tax Reform Act passed during the Reagan Administration (*16*). This Act sought to limit the drain on the national treasury from tax-exempt debt issued by local governments for public works projects or other purposes. The Act established one class of tax-exempt debt, wiping out numerous classes that had existed previously. For this class, a maximum amount of debt that could be issued was established based upon several factors, including population. Some exceptions were provided for, including airport financing, but not HSR. Thus, HSR projects were left to compete with other local public works projects for a limited amount of tax-exempt financing. Federal legislation was passed in the early 1990s adding HSR to the exempt category under the Act (*18*).

Allen anticipates the largest financial role for the private sector to be the financing of the operating system. However, he assumes that tax-exempt project revenue bonds can be issued as the primary debt and government tax-exempt bonds will serve as secondary debt to reduce the overall capital requirements and to make the primary debt instrument more financially feasible (*16*). He states that the principal security and source for payment on these debts would be project revenues. Although it is not clear from his proposal, it would appear that he is not proposing that the source of private capital for this phase be equity investments of entities such as equipment manufacturers or construction companies. It appears that the private sources of capital are coming principally from third-party financial investors purchasing the revenue bonds.

Another aspect that is not clear in Allen's proposal is whether he believes the private sector equity for the high-risk project feasibility phase will come from participant investors or from passive investors. The difference is that the former expect more than just a financial role in the process while the involvement of the latter is strictly as a source of financial capital (*14*). Passive investment capital tends to come from third-party institutional investors such as mutual funds, bank trusts, insurance companies, pension funds, and so on. Whether or not a passive investor assumes a financial position in a project depends upon the investor's assessment of the financial risk-return relationship expected from the project. While this investor might invest in project equity, the usual means of financial investment utilized is taxable bonds or similar structured debt issued to raise capital for the project. Expected returns or interest on the debt principal are usually in the range of 10 to 20 percent (*14*).

In contrast, participant investors tend to be infrastructure development firms, equipment manufacturing/suppliers, or construction firms who seek more than just the returns from financial investment. For their willingness to provide up-front funding for the more risky project feasibility work, they expect to be awarded future participation in subsequent management, construction, or operations phases of the project (*14*). If the project moves forward, the fees earned from these latter phases help to offset the high risk of investment in the earlier phases. Furthermore, they are in addition to any investment returns that might flow from the project; such returns are expected to be in the 18 to 30 percent range over the long term of the project.

Experience in public/private partnerships indicates that participant investors are the private sector source of financing for early phases of project development (*14*). Passive investors do not provide capital for the early phases of the project development/implementation process because the projects are not sufficiently defined and the development risks are too high in these phases (*14*). It would appear that for passive investors to be the source of private sector equity in Allen's proposal, the public sector would have to guarantee not only repayment, but also an adequate return if the project did not move to completion. In contrast, the government repayment guarantee alone is attractive to participant investors who may otherwise have to commit the same resources to respond to a public request for proposals in a competitive bid environment. Furthermore, for the participant investor, if the project moves forward, there is the prospect of fees from subsequent participation in the project and the possibility of investment returns.

Thus, in exchange for the guarantee, the government saves on paying for the early phases of the development process, but only if the project moves beyond these stages. The participant investor, meanwhile, is assured of not incurring a loss and has the prospect of handsome returns if the project moves forward. Urs Greiner is critical of the magnitude of these returns, especially when there are attractive, less expensive alternatives for funding early project development phases (*19*). They suggest revolving loan fund concepts, such as the U.S. DOT's state infrastructure bank program that is financed through state grants, taxes, or bond proceeds. Another alternative is governmental forms of credit enhancement that can help to reduce coverage ratio requirements (*19*). In either case, the project benefits from lower costs of capital due to the government's tax-exempt status. Furthermore, the benefits of private-sector participation can be realized without private capital investment in these early phases (*14*).

Current Financing Options

A good discussion of the financing options currently available for high-speed rail is found in a study completed for the Piedmont High Speed Corridor (*20*). This corridor would connect Charlotte, NC, Raleigh, NC, Richmond, VA, and Washington, DC. Several of these same options are discussed in the PHSRC Interim Report, but more detail is given here.

The study examined potential funding and financing sources, which are grouped into the following categories:

- *Financing Sources for Capital Costs:* Financing sources generally provide lump-sum capital and require repayment through a stream of debt service payments, commonly termed "debt financing." These differ from funding sources that are usually in the form of grants or dedicated revenues, which do not require repayment. Debt payments are typically covered from revenues paid by users of the financed project. Some financing sources include: tax-exempt revenue bonds, project finance, general obligation bonds, state guarantee, export financing, vendor financing, equipment leasing, private equity, loans, and state infrastructure banks.

- *Funding Sources for Capital Costs:* Funding sources are normally used to cover the up-front capital costs of the system, as well as certain continuing costs, if necessary; in particular, debt service and future capital improvements. While financing sources are generally paid for by the project users, funding sources are more typically paid for by a broader base of general taxpayers. Funding sources include: federal funds, state funds, local public funds, dedicated state and/or local tax revenue, local value capture methods, regional taxation districts, and sale or lease of development rights.

- *Revenue Sources for Operating Costs:* Revenue sources are those funds raised as a result of the normal operation of the HSR service. Typical revenue sources include farebox revenue, on-board and in-station concessions and advertising, high-speed parcel transport, lease of freight, and parallel uses of right-of-way.

Each of these in the three categories above is subsequently discussed in detail in the following pages. Most of the following sections are summarized directly from the report; however, discussion and references specific to North Carolina and/or the Piedmont High Speed Corridor have been removed.

Potential Financing Sources for Capital Costs

Tax-Exempt Revenue Bonds (Backed by Dedicated State and/or Local Tax Revenue)

Tax-exempt revenue bonds are backed by dedicated tax revenue and issued to cover investment in a public asset. Exemption of the interest income from federal taxes would lower the bonds' interest costs, because by not having to pay interest income tax, investors could still achieve the same effective return on tax-exempt bonds issued with a lower interest rate as they otherwise would on taxable bonds at higher rates. The use of tax-exempt bonds would enable a higher total value of bonds to be issued for the same project revenue stream. Such bonds are relatively stable and guaranteed, have a lower interest rate than taxable debt, and provide strong backing for debt service. They should also attract adequate investor interest and secure an investment grade.

Project Finance

Project revenue bonds are backed solely by the operating revenue stream of the infrastructure system. These bonds can be either tax-exempt or taxable depending on the management/ownership structure of the HSR. Although project financing provides needed funds free from the political process that encumbers other sources (e.g., tax-backed financings), the bonds may not be able to generate sufficient investor interest in "riskier" project revenue-backed bonds and may also receive a poor investment grade rating as compared to general obligation (G.O.) bonds or those backed by dedicated revenue. This type of HSR project is new to the market, and thus is relatively untested. Without successful precedents, investors are often wary of potential risk that revenue will not be adequate to cover the debt service. Debt financing backed by farebox revenues is likely to be given a lower bond rating than other types of dedicated revenues...Revenue bonds would likely be used in conjunction with other financing sources.

General Obligation Bonds

G. O. bonds can be issued to pay for investments in public transportation facilities, and are backed by the full faith and credit of the state. The debt service would be paid out of the state treasury and the overall liability would be that of the state. Any excess revenue generated from the HSR system could likely be directed to the state if a G.O. bond is used to fund capital costs for the system. With G.O. bonds, investors would analyze the state's credit risk, rather than the risk of the project (which may be higher).

State Guarantee

Under a state guarantee, the state agrees to back project revenue debt (i.e., project finance). The guarantee would take effect if project revenues, net of operating and maintenance costs, are insufficient to pay lease and debt service payments. If such an event were to occur, the debt service would be paid out of the state treasury. Advantages to this scenario are that it reduces the finance costs (i.e., interest rate) given the lower risk associated with state credit support and that it improves chances of securing an investment-grade rating on the project finance bond issue. Among the disadvantages is the fact that it puts the state at risk should the project revenues be insufficient to cover operating costs and debt service.

Export Financing

Export/import banks offer a variety of loan programs to assist in the export of equipment. The types of loan packages offered vary from country to country. In a successful transaction, all parties benefit. The vendor gets to sell its equipment, the foreign country exports goods, and the HSR system receives attractive financing terms and the ability to secure a loan that might not have been available through a direct purchase. Typically, export/import banks only consider loans of $50 million or higher. There are many countries with export-financing institutions, each with its own set of available products, regulations, and financing terms. The ability to secure overseas financing can be relatively easy given the export/import bank's lending assistance; however, there could be legal impediments depending upon the country from which the capital is obtained. Today, most foreign rolling stock and technology vendors have U.S. manufacturing operations in order to satisfy federal "buy American" requirements. Typically, the U.S. subsidiaries of foreign firms specialize in supplier credit arrangements.

Vendor Financing

With vendor financing, suppliers offer financing to purchasers to encourage the sale of their machinery and equipment. Vendor financing allows the buyer to borrow for purchases at lower finance costs and/or longer terms as compared to separate financing of the equipment (e.g., bank loan). Vendor financing may be used to finance rolling stock acquisitions and could be explored for other capital costs such as signaling systems. Vendor financing can take many forms and can be tailored to suit the individual needs of a specific purchase. The final financing package often includes a leasing arrangement. Financing, however, is based on the vendor's cost of funds, which may be higher than the cost of the state's tax-exempt debt.

Equipment Leasing

Substantial cost savings in the financing of facilities and equipment can be achieved in the United States through the use of a tax-oriented lease in which the lessor claims and retains the tax benefits of ownership (consisting of tax depreciation deductions) and passes through to the lessee most of such tax benefits in the form of reduced rental prices. The lessor claims depreciation deductions and the lessee deducts the full lease payment as an expense. Another available option might be an operating lease, which is essentially a short-term rental (potentially cancelable at any time by the lessee). A short-term lease will result in a greater required payment from the lessee over the long term. Realization of tax benefits for the lessor result in a lower cost to the lessee than other forms of financing. The rail equipment leasing market is also well developed, and numerous leasing firms could compete for this business.

Private Equity

Private-sector equity investment in a corporation is raised through the issuance of shares of common stock. A concessionaire also provides equity to the extent that it is asked to invest its funds in system capital. Common stock would provide an up-front source of financing for capital needs, reducing the need for other sources; however, the state would forego some control over the HSR system to its private shareholders. Though there are no guarantees of returns to investors or concessionaires, investors will only be attracted to the extent that they feel confident in the ability of the system to provide net income and profits.

Loans (Commercial and Institutional)

Commercial lending is the most popular financing source for infrastructure projects in developed countries. Commercial loans are made by commercial banks, for fixed periods of typically 5 to 8 years, with floating or fixed interest rates. Depending on the level of risk involved with a project, a commercial loan might be difficult to secure. Institutional investors might also make loans to finance infrastructure projects. These loans differ from commercial loans in that they typically involve fixed rates and are made for a longer term. Often the projects seeking institutional support involve high risk or other special features that would limit the ability to secure a loan through a commercial bank. This conventional method of securing financing for a project is available in the early stages of the project, although high levels of project risk might preclude the ability to secure a commercial loan. Commercial loans and institutional investor financing also have a greater cost than the issuance of bonds; however, issuing investment-grade bonds might be more difficult than securing a loan.

State Infrastructure Bank

The 1995 National Highway System legislation established a State Infrastructure Bank (SIB) Pilot Program. The legislation directed U.S. DOT to approve entities that would capitalize their transportation infrastructure banks using 80% federal and 20% state transportation funds. Ten state SIBs were approved as part of the program. In September 1996, Congress passed legislation enabling U.S. DOT to designate additional qualified states to participate in the SIB program. It is not clear to what extent HSR systems would be allowed to benefit from infrastructure banks, since the federal funds would come from the existing highway and transit funding apportionment, which already fall short of meeting highway and transit needs and which for the most part cannot be used for intercity rail investment. However, funds would revolve through a loan fund to benefit a series of highway, transit, and other transportation projects on an ongoing basis, rather than using the funds for direct, one-time grants. Intercity rail may benefit from SIB funds indirectly through allowable grade-crossing improvement projects (because grade crossings benefit from highway funding programs). Financing costs might be lower than for a direct debt issuance. SIBs pose the same limitations as federal funds for a HSR system, because the SIB is capitalized with federal funds.

Potential Funding Sources for Capital Costs

Federal Funds

There are currently a number of federal programs funding various areas in high- speed rail planning, research, and corridor development. These funds provide a guaranteed money source in the form of a grant that does not need to be repaid. Federal funds often require a matching grant at the state and local levels; future federal funding levels are also difficult to predict, and any federally funded improvements would be subject to certain federal regulations. Current federal funding programs for high-speed rail focus mainly on technology development with a goal of greater safety and greater operational efficiency. (For further detail regarding federal funds, the reader may wish to refer to the TEA 21 discussion in the next section).

State Funds

State sources of funding can take many forms, depending on the state and the type of project being funded. There is a clear link between state funding and in-state economic and transportation benefits; state funding can also be guaranteed and requires no repayment. Securing such funds through the annual state budget process, however, can be difficult.

Local Public Funds

Local funds are represented in the form of a "match" to other federal and state funds offered for the HSR system or as a direct grant for station improvements. Local funds are grants that do not need to be repaid, although securing local general revenue could be difficult and would depend on varied local support of the project.

Dedicated State and/or Local Tax Revenue

A dedicated revenue source is a legislated tax or fee imposed on a reliable source to pay for capital costs or for debt service on bonds issued to fund some infrastructure development. Such a funding source is relatively stable, has a solid history on which to forecast future flows, requires no new taxes, and requires no annual budget reauthorization. Securing dedicated revenues is difficult due to the many competing sectors of government and potential voter disapproval. Any state tax used for the purposes of issuing debt requires legislation and then a referendum, which may be very hard to accomplish because the entire state would be asked to approve investment in a geographically limited corridor. Taxation not used for the purposes of issuing debt service does not require a referendum, but a proposed increase in taxes may be politically contentious. Allocating an existing tax would be difficult for budgetary reasons.

Local Value Capture Methods

In order to capture revenues associated with enhanced real estate development resulting from improvements in transportation corridors, jurisdictions have created special assessment districts (SADs), which impose real estate taxes and collections. For transportation infrastructure developments, these funds are usually dedicated to debt service for station development projects. Similar in concept to special assessment districts, tax increment financing looks to gains in property value, economic activity, and related revenues as a source of funding. This value is measured by the increased property tax revenue created by development in a specific area. SADs provide a guaranteed revenue source and can be designed to meet local needs. Tax-increment financing is an allocation of incremental tax revenue increases; therefore tax rates will not change as a result of a tax-increment bond issuance. Infrastructure financed by the bonds issue is often designed to attract new development which, in turn, generates additional tax revenue.

SADs may require special legislation and may result in public objection and conflict with zoning laws. Revenue sources in tax-increment financing, moreover, are speculative and may not be available during the early stages of a project. The availability of this funding source depends on the willingness of local governments to create SADs and tax-increment financing districts to be used for station improvements in conjunction with HSR. The magnitude of funding available would probably only be sufficient to cover part of the station capital and/or operating cost centers.

Regional Taxation Districts

Similar to tax increment financing but on a broader scale, a regional taxation district (RTD) is established to pay for the costs of infrastructure development, often spanning the entire region benefitting from the infrastructure. RTDs provide, for a geographically limited project, the ability to use tax revenues to back debt, with the majority approval of a referendum required only in the district. Forming a district between all the counties in the HSR corridor could be a difficult process, involving public hearings and approvals throughout the corridor. It is conceivable that once some counties are on board, others will follow suit so as not to be left out, given an approach where inclusion in the district may assure the county of a station stop.

Sale or Lease of Development Rights

Under this scenario, [the HSR system] sells or leases property it owns at or near the new infrastructure facility to a private owner who wishes to develop the land. Selling or leasing development rights can provide a source of cash or be part of a joint development strategy for stations. Such action also provides supplemental revenue which can be in the form of sale or lease payments. The price sold may be a lower price than that achieved at a later stage of development, however, and environmental and zoning concerns may arise from development proposals. This public-private partnership funding source assumes that the HSR system, the state, or the localities own some land that is able to be developed adjacent to the HSR stations.

Potential Revenue Sources for Operating Costs

Farebox Revenue

Farebox revenue is revenue that is directly generated by the HSR service. It is a function of the number of riders purchasing tickets at various fares for travel on the HSR system. It is difficult to accurately predict ridership (and thus farebox revenue) before the HSR system is in operation. Thus, this revenue is poor to rely on as a source for debt service.

On-Board and In-Station Concessions, Advertising

On-board concessions would involve the sale of goods and services on the train such as food, beverages, telephone. In-station concessions would involve such sales as food, beverages, telephone, books and magazines, parking, and other items. Advertising revenue would come from selling space in and around the station, and possibly posters on-board. Concessions provide a relatively predictable revenue and allow for needed passenger-related services while transferring risk to the concessionaire. Concessionaires can also be responsible for some station improvements, and services provided are desired by passengers and increase overall customer satisfaction.

High-Speed Parcel Transport

This involves the transport of U.S. mail or expedited parcel delivery on HSR trains. While parcel transport services are relatively easy to implement, since the negotiated agreements take advantage of existing schedules and stops, the industry is highly competitive.

Lease of Freight

Under this scenario, [the HSR system] would lease the right-of-way to another railroad for freight rail operations. In turn, the railroad would pay an annual lease fee and assume responsibility for the maintenance and dispatch of the right-of-way. A lease provides a stable stream of revenue over the length of the agreement and some risk is transferred (maintenance and dispatch on right-of-way).

Parallel Uses of Right-of-Way

This approach would involve leasing longitudinal rights to the use of part of [the HSR system's] right-of-way, typically for a period of 20 or more years to firms in the telecommunications, power, or gas utility industries. The leases would provide a predictable stream of income for a long period of time. Such parallel uses, however, could complicate future right-of-way improvements. The most likely use for the right-of-way would be for fiber optics (telecommunications).

TEA 21 Innovative Financing

As alluded to previously, the recently enacted Transportation Equity Act for the 21st Century (TEA 21) provides for innovative financing for surface transportation. Specifically,

> TEA 21 creates additional innovative financing tools to address pressing transportation infrastructure needs. TEA 21 creates a new Federal program to provide financial assistance to revenue-generating surface transportation projects. Under this program, the Secretary may approve secured loans, lines-of-credit and loan guarantees for highway and bridge projects, transit projects, inter-city bus and passenger rail projects and Amtrak capital improvements costing $100 million or more. The Secretary may make up to $10.6 billion in credit available over six years. TEA 21 provides $530 million over six years to cover subsidy costs required by the Federal Credit Act of 1990. TEA 21 creates a State Infrastructure Bank pilot program that allows four States to use their Federal-aid highway and transit apportionments to fund State Infrastructure Banks (SIBs) to assist projects (*21*).

As further stated on the Federal Highway Administration's Internet web site:

> TEA-21 builds on the innovative financing initiatives begun under ISTEA to leverage Federal resources by encouraging private participation in the delivery of surface transportation infrastructure. These initiatives are intended to supplement the traditional Federal-aid grant assistance by increasing funding flexibility and program effectiveness. They establish pilot programs to test new finance mechanisms, and they extend or make permanent some of the tools already tested (*22*).

> ***Direct Federal credit.*** The Act establishes a new program, under the Transportation Infrastructure Finance and Innovation Act (TIFIA), through which DOT can provide credit assistance on flexible terms directly to public-private sponsors of major surface transportation projects to assist them in gaining access to the capital markets. TIFIA provides a total of $530 million of contract authority over FYs 1999-2003, and authorizes the Secretary to collect fees from borrowers, to fund up to $10.6 billion of direct loans, loan guarantees, and lines of credit to support up to 33 percent of project costs. Eligible projects include highway and capital transit projects under Titles 23 and 49, international bridges and tunnels, intercity passenger bus and rail projects (including Amtrak and MAGLEV systems), and publicly owned intermodal freight transfer facilities on or adjacent to the NHS. Projects must cost at least $100 million or 50 percent of a State's annual apportionments (except $30 million for ITS projects) and be supported by user charges or other dedicated revenue streams. The Secretary will evaluate and select eligible projects based on a variety of factors, including national significance, credit-worthiness, and private participation (*22*).

Some additional information contained in the FHWA web site includes "fact sheets" regarding high-speed rail and magnetic levitation (*23*). Specifically:

High-Speed Rail

Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Planning	$45M	$10M	$10M	$10M	$10M	0	0
Technology	$40M	$25M	$25M	$25M	$25M	0	0

Program Purpose

The high-speed rail program is designed to extend the life of an existing high-speed rail corridor planning and technology development program.

Funding Features

The high-speed rail provisions of TEA-21 extend authorizations of appropriations for the existing high-speed rail assistance program created in the Swift Rail Development Act of 1994 (49 U.S.C. 26101 et seq.).

The TEA-21 authorization covers fiscal years 1998-2001 and is a General Fund authorization, which means that the funds must be made available in an Appropriations Act before the program can be implemented.

The Secretary is authorized to provide financial assistance for up to 50 percent of the publicly financed costs of corridor planning activities and up to the full cost of technology improvements.

Eligible Use of Funds

The program authorizes the Secretary to provide financial assistance:

- to public agencies for high speed rail corridor planning activities and certain other pre-construction activities, including right of way acquisition;
- to any United States business, educational institution, State or local government, public authority, or Federal agency to support the development of high-speed rail technology improvements.

Magnetic Levitation Transportation Technology Deployment Program							
Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Contract Authority	0	0	$15M	$20M	$25M	0	0
Authorization (subject to appropriation)	0	0	0	$200M	$200M	$250M	$300M

Program Purpose

The magnetic levitation transportation technology deployment program encourages the development and construction of an operating transportation system employing magnetic levitation capable of safe use by the public at a speed in excess of 240 miles per hour.

Funding Features

Contract authority out of the Highway Account of the Highway Trust Fund is provided for fiscal years 1999-2001 totaling $60 million.

- $55 million is available to fund preconstruction planning activities and design/construction of the selected project.

- $5 million is available only for research and development grants related to low-speed superconductivity maglev technology for public transportation purposes in urban areas.

An authorization for an appropriation out of the Highway Account of the HTF is provided for an additional $950 million over fiscal years 2000-2003. These funds would have to be appropriated by the Congress before they would be available for expenditure.

An eligible maglev project would also be eligible for other forms of financial assistance provided in Title 23, United States Code, and TEA-21, including loans, loan guarantees, and lines of credit.

The Federal share of full project costs (the total capital costs of a maglev project, including fixed facilities and stations, vehicles and equipment) cannot be more than 2/3, except that States may use STP and CMAQ funds to pay all or a portion of their share of full project costs of an eligible project, without the requirement for non-Federal funds.

There is no matching requirement for low-speed maglev research and development grants.

Eligible Use of Funds

The Secretary is authorized to provide financial assistance to States (or authorities designated by one or more States) to fund

- preconstruction planning activities (such as preparation of feasibility studies, major investment studies, environmental impact statements) of one or more feasible high-speed maglev system;
- final design, engineering and construction activities for one high-speed maglev system to be selected by the Secretary;
- grants for research and development of low-speed superconductivity magnetic levitation technology related to public transportation in urban areas.

Qualification Requirements

To be eligible, projects have to

- exhibit partnership potential;
- be able to be constructed with available Federal and non-Federal funding;
- result in an operating transportation system in revenue service;
- be undertaken through a public-private partnership;
- satisfy applicable statewide and metropolitan planning requirements;
- be approved by the Secretary based on a State application;
- be carried out as a technology transfer project to the extent non-U.S. maglev technology is employed;
- involve materials at least 70 percent of which are manufactured in the United States.

Selection Criteria

Statutory project selection criteria (e.g. national importance of the project, project contribution to reducing congestion, non-Federal financial support, job creation, etc.) are included to guide the Secretary's decision in determining which project to fund for final design and implementation.

4. Intercity Passenger Demand Forecasting for High-Speed Rail

Introduction

This section addresses the issue of passenger demand forecasting for intercity high-speed rail service. Travel demand forecasting is a difficult, inexact science, even for relatively short periods into the future for established forms of transport, let alone for a 20-year time horizon and for a new mode such as HSR. Quality forecasting efforts require sophisticated modeling techniques, significant amounts of data, and a clear understanding of the impact many socioeconomic, cultural, and individual characteristics and preferences have on travel behavior. Travel forecasting is difficult because there is not a perfect understanding of travel behavior. It is more complicated for HSR because there are no such systems operating in the United States to learn from other than the Northeast Corridor. While several systems do exist in Europe and Japan, the modal competition conditions, land-use patterns, population densities, and cultural affinity for mass forms of transport are very different from the United States.

Because forecasting currently is an inexact science, forecasting professionals face numerous decisions requiring their best professional judgment over the course of a forecasting effort. In the case of HSR, advocates and critics will try to influence the forecaster's judgment. However, because forecasters producing estimates for a given project tend to work more closely with the project promoters than with the critics, there is a danger of the promoter's enthusiasm for the project clouding the forecaster's judgment such that overly optimistic forecasts are produced. Commenting on HSR demand forecasting, one observer paraphrases Winston Churchill: "seldom in the field of economic endeavor has so much been projected for so many based on so little" (*24*).

This discussion is concerned with advances that have been made in intercity travel demand forecasting since the completion of the PHSRC study in the mid-1980s. The discussion focuses on three topics: theoretical understanding of trip-making behavior; modeling techniques; and data availability, collection, and presentation. Before addressing these items, an overview of travel demand forecasting is given, followed by a brief review of the forecasting efforts of the PHSRC.

Overview of Travel Demand Forecasting

The end product of passenger demand forecasting for HSR is an estimate of the number of HSR trips made in the forecast year between each major origin and destination pair within the study area. The basic modeling approach begins with theoretical assumptions on travel demand behavior. These assumptions largely determine the model type or specification (structure, form, and variable specification) and the data requirements.

The general structure of what has come to be known as the classical four-stage transport demand forecasting model was developed in the 1960s. The classical model, shown in figure 1, continues to be the most widely used modeling structure despite significant advancements in modeling techniques (*25*). The model begins with a specification of the base year, the division of the study region into geographic zones, and the collection or estimation of base year data. The base year data collected or estimated generally include descriptors of the transportation network, service-level characteristics of transport service providers, travel volumes on the network, and demographic and economic characteristics of each zone. The specific data items or variables collected depend upon the theoretical assumptions initially made about travel behavior.

The base year data are used to build (calibrate) and validate the parameters of the four-stage model. This model attempts to replicate the base year travel conditions. The travel behavior assumptions dictate whether or not multiple models are estimated for alternative income levels and trip purposes, such as business, commuting, or pleasure trips.

Stage one of the four-stage model estimates the total number of trips made from each zone (trip generation). Stage two distributes these trips to destination zones, thus producing an origin/destination trip matrix. Mode split, stage three, allocates the trips to the various mode alternatives, while stage four assigns trips to alternative routes in the transport network. The latter stage is rarely relevant in a HSR study, as there generally is just one relevant HSR route.

Following base-year model calibration and validation, the model is used to estimate forecast-year trips. Forecasts of all model input variables, such as demographics, economic conditions, and cost and service characteristics of the future transport system are applied to the model to generate the forecast-year trips.

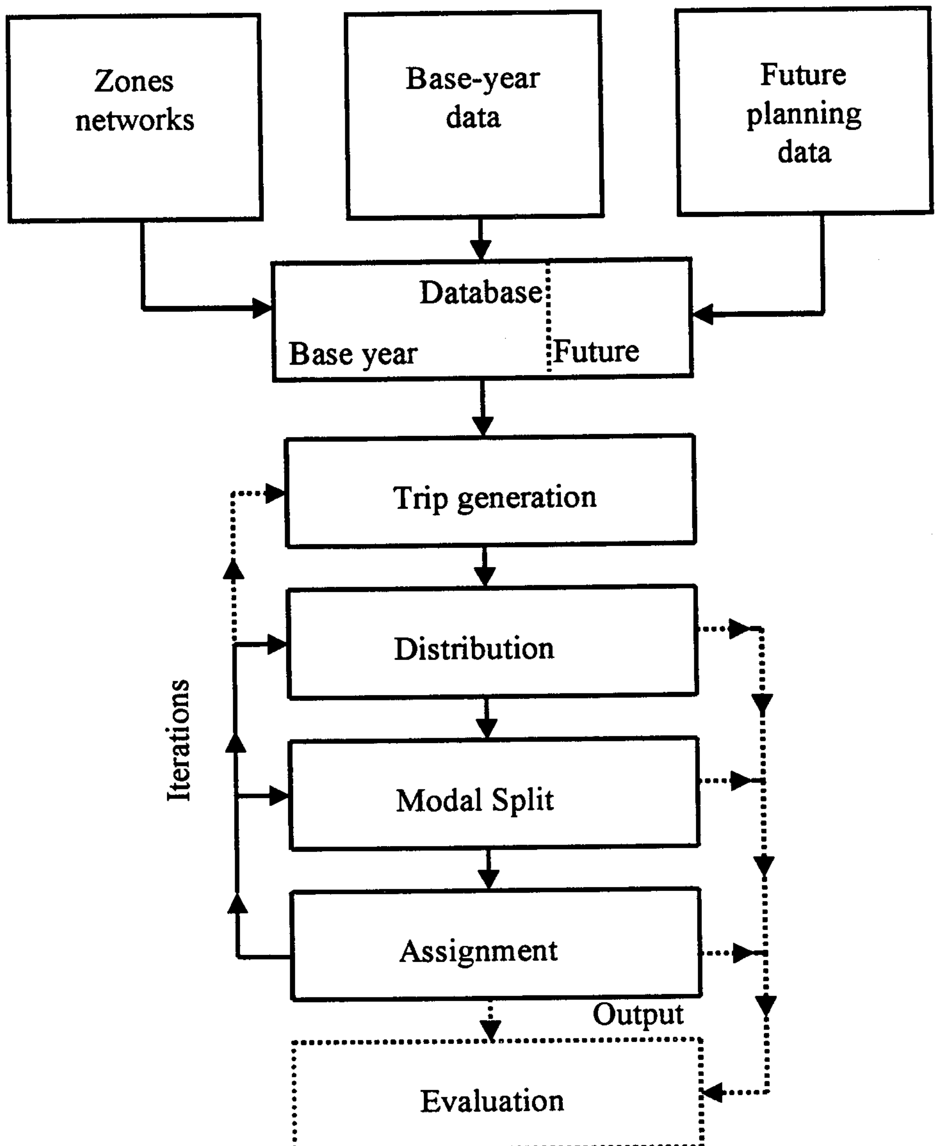

Figure 1. The classic four-stage transport model
Source: Ortuzar and Williamsen, 1994

Travel Forecasting Methodology Used by the PHSRC[4]

The PHSRC used a two-stage, sequential forecasting model, a variant of the classical four-stage model. Stage one combined trip generation and distribution into one model to produce a base-year, intercity origin/destination trip table. Each origin or destination zone was one of 43 Pennsylvania counties in the study area or one of a few out-of-state zones. Stage two then performed the mode split. Both stages were conducted for four alternative trip purposes.

A major shortcoming and the principal handicap for the PHSRC forecasting efforts was the lack of base year data. The base year trip tables had to be manufactured from either very old or incomplete data sources. For example, a 1963 statewide origin and destination automobile trip study, by trip purpose, by Edwards and Kelcey, served as the principal source of data for the base year (1980) intercity trip tables.[5] A growth factor model and national-level changes in trip-making propensity were used to adjust the 1963 auto trip data to the base year. The same basic technique was then used to estimate the forecast-year (2000) trip tables for each trip purpose.

Growth factor models assume that future trips between an origin/destination pair change in direct proportion to changes in population and employment of the pair. They also assume that either trip-making between each origin/destination pair is unaffected by changes in the transportation network, or that such changes will be insignificant over the study period (*26*). For the PHSRC study, the study period, in effect, became 1963-2000 due to the limitations on data availability. Of course, it is well known that trip making is affected by changes in transportation systems. Further, the highway network in Pennsylvania will have changed considerably between 1963-2000 and this likely has significantly affected travel patterns in the state.

The PHSRC mode-split modeling approach was very close to if not state-of-the-art, for intercity demand modeling in the mid-1980s. Economic consumer behavior theory provided the theoretical framework for the model. Variables well known to affect mode split, such as travel time, cost, service frequencies, access distance to carrier stations or terminals for each mode and income of the traveler, were included. The fact that four different trip purposes were modelled was an advancement over most previous approaches that used just two. Also, stated preference techniques were used to improve the ability of the model to predict traveler choices when faced with the introduction of a new mode or service, such as high-speed rail.

However, the logit functional form used in the model, while advanced, suffered from the independence of irrelevant alternatives (IIA) property. The practical effect of IIA is that each of the alternative modes of transport is equally sensitive (equal-cross elasticities) to the introduction of HSR service. In other words, predicted HSR ridership is drawn in direct proportion to the

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[4]The information on the PHSRC forecasting methodology presented in this section is drawn from two sources: Parsons Brinckerhoff/Gannett Fleming, Pennsylvania High Speed Feasibility Study, Preliminary Report, January 1985; and Parsons Brinckerhoff/Gannett Fleming, High Speed Rail Feasibility Study, Phase 1, Memorandum Report B, Demand Estimating Methodology, February 28, 1984. Modifications to the models reported in these sources may have been made in 1985 and 1986, but the reports documenting those modifications could not be obtained in sufficient time for this review.

[5]An estimated 99 percent of the person-trips in the Philadelphia-Pittsburgh corridor are made by automobile *(30)*.

share of trips made on existing modes (*27*). If 90 percent of the intercity trips are made by auto, 8 percent by air and 2 percent by bus, then 90, 8, and 2 percent of the predicted HSR ridership will be diverted from auto, air, and bus, respectively. This is not logical choice behavior. Fortunately, advances in modeling techniques have addressed the IIA problem through application of the nested logit model or the adoption of the probit functional form (*28*).

Another concern with the PHSRC mode split methodology is that the model used was developed for another study of intercity travel (without a HSR alternative) and then recalibrated for the HSR study. Transferring models from one location to another has been closely studied and criticized for the large errors potentially introduced into the forecasts (*29*). However, others argue that transferring models is a practical approach in situations where there are insufficient resources for an adequate data collection effort, particularly if appropriate attempts are made to modify the model parameters to better represent the new application environment (*25*). Such an adaptation was attempted by the PHSRC but, unfortunately, the attempt produced the illogical result of bus being the second most favorable mode for intercity business travelers (*30*).

Another unfortunate aspect of the PHSRC forecast methodology was the decision to use full coach air fares in the mode-split model while at the same time introducing HSR competition for air carriage (*30*). This is not an uncommon practice in intercity HSR studies, yet it seems unlikely that air carriers would not respond with lower fares in the face of new competition.

Advances in Travel Demand Forecasting

The purpose of this section is to outline some of the major advances in travel demand forecasting that have been made since the PHSRC completed its work. As was done previously, the discussion is generally organized around three topics: theoretical understanding of travel behavior; modeling techniques; and data availability, collection and presentation.

Behavioral assumptions regarding travel behavior

The classical forecasting models focus on person or vehicle "trips" as the principal unit of analysis. Trips however, are simply a consequence of a prior sequence of decisions regarding activities, such as commuting, shopping, vacation, and so on, that people decide to undertake. In other words, the demand for travel is derived from the demand to engage in various activities (*31*). By using a trip-based rather than activity-based framework, the classical models are not able to address directly those issues that generate trip-making behavior; they cannot assess, for example, the substitution of teleconferencing for intercity business trips nor how changes in buyer-supplier relationships, such as a JIT contract or a supply chain logistics partnership, affect the propensity of travel between buyer and supplier facilities. Thus, most travel behavior research over at least the last 15 years concludes that individual daily, weekly, and seasonal activity patterns should form the demand modeling framework (*31, 32*).

A consensus has also formed on the belief that travel behavior is stochastic or probabilistic rather than deterministic (*31*). Deterministic models assume that two people faced with the same travel conditions and alternatives make the same travel choice. Stochastic models recognize that different biases, preferences, perceptions, or levels of information create uncertainty in predicting the choice of an individual traveler.

However, it is assumed that this uncertainty is distributed according to a known probability distribution and that this distribution can be used to predict accurately the distribution of choices of a group of trip makers, even though the choice of an individual trip maker cannot be predicted with certainty. The PHSRC mode-split model was stochastic, but the joint trip generation/distribution model was deterministic.

The classical models assume that travelers make rational economic choices when faced with the value of a set of travel conditions. However, recent travel behavior research indicates that there may be lags in response that vary in length between individuals when these individuals are faced with changes in transport system price and service. There may also be different responses among individuals depending upon the direction or magnitude of change (*31*). The PHSRC models were not capable of capturing this adaptive behavior. It is recommended that data from longitudinal panel surveys be analyzed and modelled to better capture these adaptive responses (*31*).

Modeling techniques for intercity travel

Modeling techniques have improved such that significantly more accurate travel forecasts can be developed with less data than could be done in the mid-1980s. Some of these improvements are discussed in this section.

One such improvement is the expanded use of disaggregate choice models in substitution for aggregate models. The aggregate models lacked a well-grounded travel behavior basis and their model estimation methods produced badly biased model parameters. These deficiencies combined with the multiplicative functional form of the total demand model produced overestimation errors of as much as 50 percent (*32*). The disaggregate models can be formed in a more behaviorally consistent fashion and they do not suffer from the same overestimation bias problems (*32*).

The modeling techniques of the classical forecasting model relied on data-collection surveys designed to capture, via observation, the travel choices people make. Known as revealed-preference methods, they did not work well when trying to model new travel alternatives, such as high-speed rail. By the mid 1980s, stated preference techniques using hypothetical scenarios were commonplace in applications involving new travel choices (*33*). Indeed, the PHSRC used stated-preference techniques in Phase II of its work (*34*). Unfortunately, early experience with stated-preference techniques found they produced a wide range of estimates and did not satisfactorily solve for new alternatives. However, a lot of stated-preference experience has been accumulated since 1985; consequently, much more is known about how to use the techniques properly and in complementary combination with revealed-preference data (*35*). A move to scenario-based interactive survey design methods appears to be producing positive results (*36*).

As indicated previously, the logit model used for mode split by the PHSRC suffers from the IIA property. This problem has now largely been solved through application of the nested logit, probit, or generalized logit models.

Microsimulation is being used in combination with stochastic, activity analysis approaches to produce better, more stable model parameters. Microsimulation appears to increase forecasting model sensitivity to items such as congestion and availability of traffic information (*31*). Applications of microsimulation have principally been in urban area forecasting.

Data availability, collection, and presentation methods

The lack of good travel data severely constrained the quality of the demand forecasting efforts of the PHSRC. Unless new data collection efforts are undertaken, then any future forecasting efforts for HSR in Pennsylvania will be similarly inhibited.

Koppelman has put forth the general categories of data that are needed to support disaggregate intercity demand modeling (*32*):

- Description of the existing transportation service alternatives in the study area. Description includes items that influence traveler usage, such as frequencies, line haul travel times, reliability performance, rates, access/egress travel costs, time, interconnectivity convenience, and ease of purchasing tickets or paying fares;

- Existing intercity travel volumes, by mode, type of origin and destination, trip purpose, and fare/service class;

- Demographic, socioeconomic, and other travel-influencing characteristics of the study area;

- Detailed individual travel behavior survey data, collected periodically over time, including lifestyle characteristics and "preference rankings" or observed choices among a variety of real and artificial service alternatives.

Some of the new techniques for collecting the detailed individual travel data include situational approach methods such as household activity diaries, longitudinal (over time as opposed to cross-section) panel surveys, stated response surveys, and improved stated-preference surveys (*31*).

Geographic information system (GIS) technology has greatly improved data management and the ability to convey ideas to decision makers and the public. Existing modeling techniques built on a GIS platform are capable of modeling trip generation on a house-by-house and business-by-business basis, thus avoiding the need to assume all trips associated with a given transportation analysis zone originated or terminated at the zone centroid. This change greatly improves the ability to model accurately the importance of station or terminal access and egress times and distances.

Comparison of Forecasts

As a matter of interest, the maps in figures 2 and 3 present some comparisons relevant to forecasting. The figure 2 map compares the percent change in population between 1980 (base year for the PHSRC) and 1990 for the counties in the HSR study area. Population was one of the principal variables affecting the trip generation forecasts made by the PHSRC. The dark line is the rough alignment of the HSR system for Pennsylvania. Those counties in various shades of green have gained population, with the fastest-growing counties being shown in the darkest shade of green. Counties that have actually lost population over this period are shown in yellow, orange, or red, with the latter experiencing the largest percent decline. As expected, most of the counties in the central and eastern portions of the state have grown, while many of those in the west that have undergone dramatic economic changes have declined in population over the period.

The figure 3 map compares the population forecasts made by the PHSRC for the year 2000 with year 2000 forecasts published recently by the Penn State Data Center. Counties in the darker colors indicate an underprojection by the PHSRC, while counties shown in the brighter shades indicate an overprojection. There is a fairly close correspondence between the underprojected counties and those counties that lost population between 1980 and 1990.

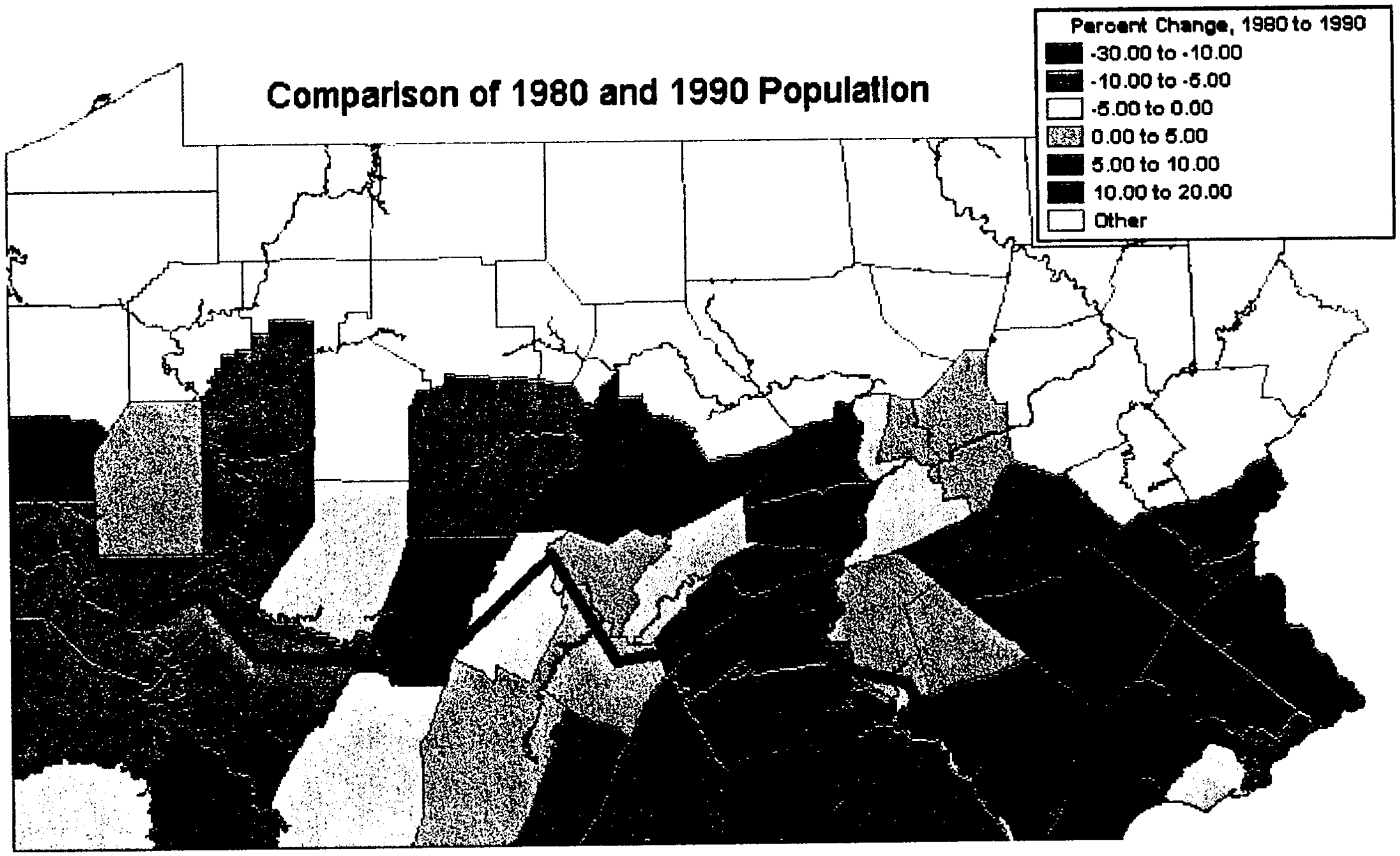

Figure 2. Comparison of the percent change in population between 1980 (base year for the PHSRC) and 1990 for the counties in the HSR study area.

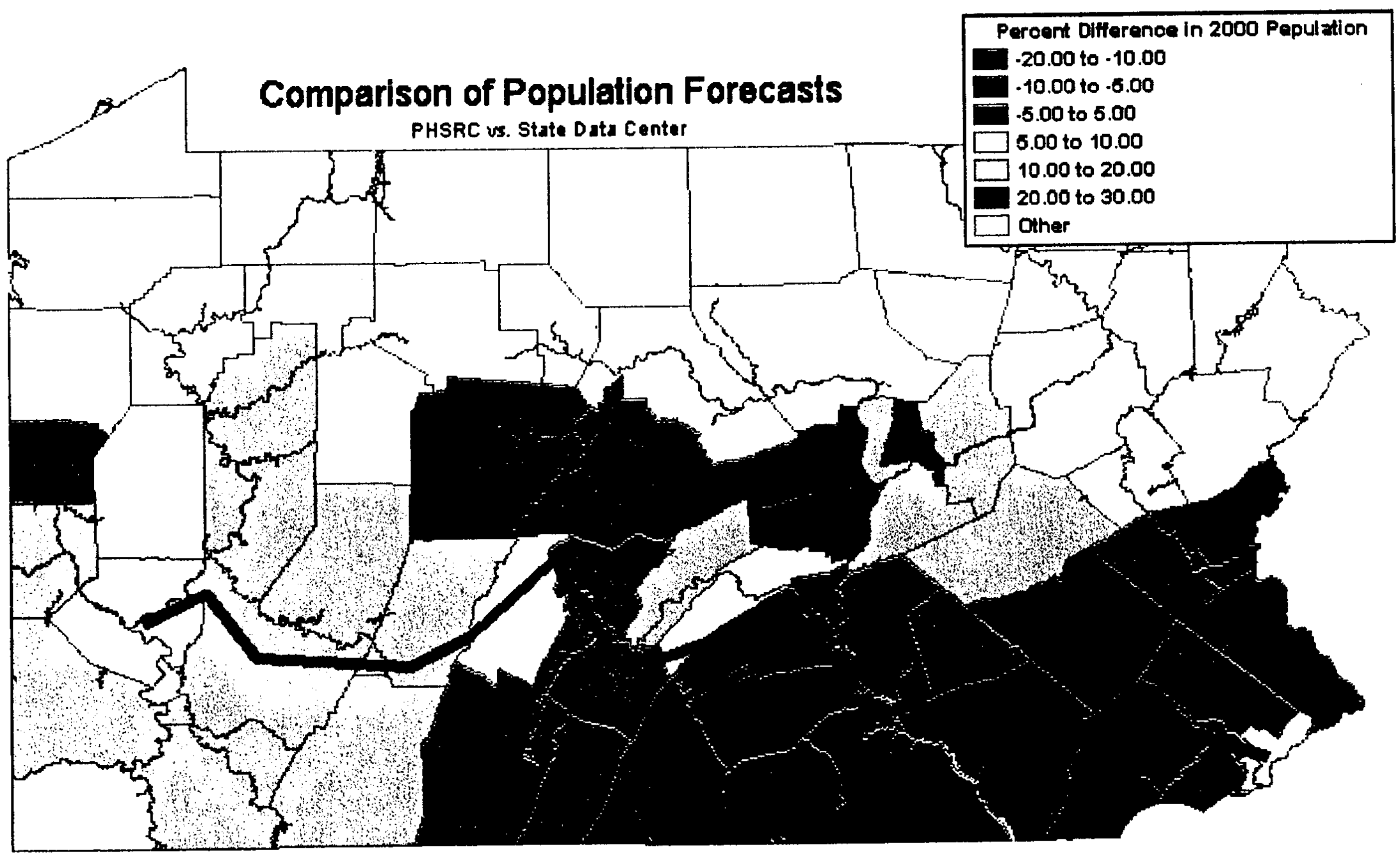

Figure 3. Comparison of the population forecasts made by the PHSRC for the year 2000 with year 2000 forecasts published by the Penn State Data Center.

Appendix A: Case Studies

There are several states that have attempted to implement high-speed rail, most notably California, Florida, and Texas. Some of the financing options each of these considered are detailed here. In addition, some of the financing mechanisms for high- speed rail in Europe are explored, as well as a brief update on what is occurring at Amtrak.

California Intercity High-Speed Rail Commission

This commission was established in 1993 to "develop a framework for implementation of a high-speed rail system in California" (*37*). It has examined both the feasibility as well as the advisability of implementation. Regarding the financing of the system:

> Detailed financial projections show that farebox and other revenues will not be sufficient to fully finance the Los Angeles-San Francisco system capital costs. While system revenues exceed operating costs by a healthy margin, the potential return on investment is insufficient to attract substantial private investment, given the inherent risks in such a large-scale project. Prices for competing modes would have to increase substantially for high-speed rail to capture enough of the market and/or charge high enough fares to change this conclusion.
>
> The financing evaluation considered different levels of financial support. Seven possible sources were evaluated for the critical base funding source, and three have emerged as the most probable, given current assumptions about economic, financial, and political viability: statewide retail sales tax; retail sales tax levied only in counties served by the system; and motor vehicle fuel excise or sales tax.
>
> Other funding mechanisms studied included airport passenger charges and highway tolls. Most of these would not generate sufficient revenue to be considered a viable source of base funding. In addition, there are institutional obstacles that would need to be addressed in order for some of the more innovative financing strategies to gain credibility, such as restrictions on interstate highway tolls, jurisdiction over airport fees, and segregation of funds by mode.
>
> Although private investment as a base funding source is unlikely in the foreseeable future, opportunities for private-sector investments and partnering do exist. These include deferred-compensation certificates for system construction and vendor financing of concession facilities. Local government participation is also an important source of financing, contributing towards, for example, station costs. These secondary and supplemental sources should be maximized, and the need for state funds reduced to the greatest extent possible.
>
> The commission recommends that implementation proceed under the assumption of base funding derived from public sources. Note that under the presently assumed financing plan, system revenues support a significant portion of the construction costs. Once the

capital debt has been repaid, the system will generate substantial excess revenue that may be returned as income to the state or used to finance additional high-speed rail projects.

Texas High-Speed Rail Authority

The Texas TGV project was canceled in August 1994. The project was to connect Dallas, Houston, and San Antonio with a "privately financed high-speed train system" (*38*). It appears that this commission attempted to use the franchise idea explored earlier. The Texas TGV Internet web site provides a brief description of what happened:

> The Texas High Speed Rail Authority awarded a fifty-year high speed rail franchise to the Texas TGV Corporation on 28 May 1991. Texas TGV was a consortium made up of Morrison Knudsen (USA), Bombardier (Canada), GEC-Alsthom (France/UK, builder of the TGV) and a group of financial institutions comprising Crédit Lyonnais, Banque IndoSuez, Merril Lynch, and others. Texas TGV won the franchise after over two years of litigation opposing it to a rival consortium backing German ICE technology. The franchise covered the design, construction, ownership and operation of the high speed rail system.
>
> Texas TGV agreed to secure funding for the project entirely from private sources, since the state of Texas did not allow the use of state money. The project, with an original estimated cost of 5.6 billion dollars, got off to a rocky start. The first job was to conduct an environmental impact study, for the sum of 170 million dollars. The money proved difficult to assemble, and Texas TGV was granted a one-year extension by the Texas High Speed Rail Authority. This extension expired on 31 December 1993, and in the last few weeks leading up to it there was a mad scramble to secure the money.
>
> At this time, the Warburg bank of London was able to issue 200 million dollars in bonds to finance the project. These bonds were purchased by European investors with the understanding that after two years they would either be payed back by Morrison Knudsen (in charge of the civil engineering for the project, including the environmental impact study) or converted into shares of the Texas TGV Corporation. Two days before the evaluation meeting of the Texas High Speed Rail Authority, Morrison Knudsen's Bill Agee made it known that his company would not guarantee the bonds. The financing fell through, and the project sailed past the deadline without any money in sight.
>
> In the meantime, the project's overall estimated cost soared to 6.8 billion dollars. Southwest Airlines, a low-cost airline serving the short haul market in the Texas Triangle, lobbied hard against the Texas TGV project, since it was clear that Southwest's business in the area would be drastically impacted. Southwest was started on the Texas Triangle in 1971.
>
> In August of 1994, the state of Texas decided that the Texas TGV Corporation had failed to live up to its promises, and withdrew the 50-year franchise for high speed rail development. By this time, the consortium had invested about 40 million dollars.

Florida High-Speed Rail Transportation System

Florida is a story of where there was early optimism for an HSR system entirely financed and operated by the private sector, which now recognizes that substantial public support will be required, as it is for most transport facilities.

In the early 1980s optimism was high in Florida that high-speed passenger rail systems could be fully capitalized and operated without public financial support (*40*). The basis for this viewpoint lies in popular conservative principles of smaller government and privatization and in a belief that changing economic conditions (higher petroleum prices and congested air and highway systems) were favorable for rail transport.

Findings in early studies seemed favorable and were widely quoted or perceived to conclude that HSR in Florida could be developed without public financial support. But there were critical underlying assumptions, such as right-of-way provided by government at no cost or substantial capital generated from the granting of development rights at HSR stations, that were not initially well publicized and led to a public and political misunderstanding; this, in the opinion of at least one participant, hurt Florida HSR efforts in the long run (*40*).

Subsequent, more detailed studies and actual proposals from potential HSR construction and operating franchisees concluded that public financial support for capital expenses would be necessary. The early optimism for development rights as a source of capital could not be reflected in financing plans–the principal potential franchisee concluded that while development rights had potential value, their uncertainty made quantification of this value too difficult and speculative for the procurement of bonds (*40*).

Value-capture revenue was another real estate-related revenue source that rose in importance in proposed financing plans only to be eventually eliminated. Where authorized, local governments may levy impact fees, special benefit assessments, or tax increments to capture the increase in property values resulting from a transportation improvement and to provide revenue for the financing of the improvement. These, too, were viewed as having significant revenue potential, but had to be eliminated from financing plans due to a lack of local government support, which had waned in the face of earlier misunderstandings on the need for public financial support (*40*).

After these earlier problems Florida had in securing funding for high-speed rail, it appears Florida is getting "back on track" by taking more of the public/private partnership and franchising approaches as have been discussed previously. As stated in the Internet web site (*39*):

> The award of the high speed rail franchise to Florida Overland eXpress (FOX) in early 1996 culminated many years of planning by the Florida Department of Transportation (FDOT) and private sector companies concerned with Florida's future transportation needs.

Like airports, the Florida high speed rail system will be financed with revenue bonds, initially secured by a combination of state and federal funds and private equity. After several years of operation and building its ridership and markets, system revenues will be sufficient to cover all operating costs, debt service on the revenue bonds and generate a significant surplus that can be used to pay back the public investments, expand the system, or add local feeder lines.

The Florida high speed rail system is also being planned as a market responsive business in which all of its construction, financing and operating costs will be covered by system revenues (mainly fares) over the life of the franchise, a period of 40 years. Financing for the system will be secured from several sources:

- First, FDOT has programmed $70 million per year (escalated 4% per year for growth and inflation) from existing transportation revenues accruing to the transportation trust fund. These funds can support about $1.4 billion in revenue bonds.

- FOX will provide $349 million in private equity. During the first three years of project development, $58 million will be spent on environmental certification and project design. The remaining $291 million will be used to finance the train sets. FOX expects an after tax return on investment of 15% on a successful project but will lose its investment if the project should fail.

- Federal credit enhancements, guarantees or loans in the amount of $2 billion have been proposed as part of the new transportation authorizing legislation. The U.S. Senate has drafted the Transportation Infrastructure Financing and Innovation Act for inclusion in a new Intermodal Surface Transportation Efficiency Act bill, and if enacted, it will satisfy the credit enhancement requirements of the Florida high speed rail project. Congress is expected to take up the transportation reauthorization in 1998.

- The remainder of the funds (approximately $3.5 billion) needed to build the system will be provided from revenue bonds sold on the open bond market and secured solely from system revenues. These bonds will not be backed by department or state revenues."

The following exhibit illustrates Florida's proposed financial plan:

Total Sources and Uses of Funds During Construction Phase
(Year 1997 through 2006, in Millions, Year-of-Expenditure Dollars)

Sources		Uses	
Infrastructure Bonds	$6,732	Capital Costs	$6,242
Train Equipment Bonds	$674	Reserve Funds	$1,228
FOX Equity Contribution Bonds	$349	Capitalized Interest	$1,224
Federal Grant	$300	Bond Issuance Costs	$73
State Contribution*	$446		
Interest Earnings	$266		
Total	$8,767	**Total**	$8,767

*State Contribution for years 1997 through 2003

Total Sources and Uses of Funds for the Operating Phase
(Year 2004 through 2042, in Millions, Year-of-Expenditure Dollars)

Sources		Uses	
System Revenues	$53,414	Operating and Maintenance	$16,608
State Contribution	$6,110	Debt and Equity Service	$26,894
Interest Income	$1,856	Reserve Funds Balance	$691
Reserve Funds	$1,228	Excess Revenues	$18,415
Total	$62,608	**Total**	$62,608

In addition, some Frequently Asked Questions on system financing and the associated answers are presented at this web site (*39*). These are as follows:

Frequently Asked Questions on System Financing

1. How are the backers of the train going to get investment grade rating on the bonds that are to be issued?

The project, as planned, will require approximately $6.7 billion in total debt financing. The first $1.9 billion in bonds will be issued as "State Infrastructure Bonds" and will be backed solely by the $70 million per year (escalated at 4% per year for 40 years) state commitment to the project. With this commitment, the state will guarantee the repayment of the $1.9 billion in bonds without relying on any of the project's net system revenues. Because of this, at least an "A" category rating is likely to be achieved for the State Infrastructure Bonds.

The project will also require approximately $2.8 billion in "Senior System Infrastructure Revenue Bonds." These bonds will be backed by the project's net system revenues with a minimum of 1.75 times debt service coverage. This debt service coverage will be sufficient to ensure at least a "BBB" category credit rating for these bonds. No state or any other government guarantee will be provided for these Senior System Infrastructure Revenue Bonds.

The remaining $2.0 billion in debt financing is proposed to be obtained as a direct loan from the federal government under the Transportation Infrastructure Finance and Innovation Act of 1998 (TIFIA). This Act created a federal credit enhancement program for major transportation infrastructure facilities. The program utilizes credit enhancement methods such as direct federal loans, lines of credit and loan guarantees to help advance the financing of large nationally significant transportation projects. It would offer a new tool to leverage limited federal resources and stimulate additional investment in transportation infrastructure in the United States. The Act included a total of $530 million in federal budget authority over six years to support a maximum of $10 billion in transportation project financing nationwide. The House and Senate Conference agreement on TIFIA specifically stated that "The State of Florida's request for a Federal loan equal to 1/3 of project costs should receive favorable consideration from the Department of Transportation, provided it meets program criteria."

The current finance pro-forma for the project shows that the system will generate sufficient revenues to cover debt service payments on all project debt including the state infrastructure bonds, the system revenue bonds and the federal direct loan using system revenues and the state's annual $70 million contributions. The finance pro-forma also shows that starting in the 2019, the system revenues alone will be sufficient to cover all debt service payments and the state contributions will no longer be needed at that time.

<u>2. What guarantees has the state made in backing these bonds?</u>

The state's maximum commitment to this project will not exceed the $70 million annual contribution as stated above.

<u>3. How much money is the state going to have to cover if the train should fail?</u>

If the system's revenues as projected do not materialize, the state's commitment will remain at $70 million per year escalated at 4% annually for 40 years. The state will only be obligated to make debt service payments on the State Infrastructure Bonds. The state will provide no guarantee for the system revenue bonds or the federal loan. The bond holders will assume the risks associated with the default on the revenue bonds and the federal government will assume the risk relating to the federal loan. In addition, since the system revenues projected provide a 2.5 times coverage factor for operating and maintenance costs, system revenues will be sufficient to cover all operating and maintenance costs even if ridership is reduced by up to 55%. This scenario is highly unlikely give the level of sophistication in the ridership estimates and the sensitivity analysis that has been conducted and documented.

European Experience

A brief discussion of the financing of European high-speed rail systems is given here mainly for comparison purposes. The information was located in a book written by Dr. Tim Lynch and the reader is referred to this reference for further detail (*41*).

The main conclusion is that although "historically public transit and HSR have been publicly funded in Europe and are generally associated with provision of an essential public function–providing efficient and effective public transportation services, there is a growing need for a newly defined cooperative private-public relationship to finance needed European infrastructure–including proposed massive HSR infrastructure investments."

The author then details extensively the financing and economics of HSR systems in France, Germany, Sweden, Italy, and Spain. He then presents a case study entitled, "Lessons from Lille," which he believes may help to guide HSR development in the United States. Some of these lessons include:

- Broad-based federal, state, and local government financing is essential to implement HSR infrastructure systems in Europe and elsewhere.
- Bipartisan (or multi-party) political support across a wide spectrum of municipal governments affected by HSR is central to successful implementation of HSR systems.
- Robust and mutually beneficial public-private partnerships are essential for successful deployment of HSR systems.
- Private-sector involvement is increasingly essential in financing and planning the integration of the HSR system into the commercial fabric of the urban areas.
- Each of the public-private partners performs the functions most appropriate to their unique strength to accomplish final HSR implementation success.
- Success of the HSR system ridership is increasingly tied to the system's multimodal linkages for efficient passenger transfers and mode share transfers.

The author concludes with some interesting comparisons between European and American public transportation financing policies. The main differences noted were (1) although public subsidies for the automobile are present in each country, they are highest in the United

States; and (2) use of public transportation in the United States is mainly dominated by low and moderate income travelers, whereas in Europe, all income levels use public transportation. Both of these contribute to making high-speed rail in the United States difficult to deploy.

Amtrak

Amtrak has an on-line newsletter available at its Internet web site (*42*). The following two articles are from the April 1998 edition and the July 1998 edition, respectively:

Bombardier and GEC Alsthom: Innovation in Motion

> On May 1, 1996, Amtrak signed an agreement with the consortium of Bombardier Transit Corporation and GEC Alsthom to provide high-speed trains, electric locomotives, maintenance facilities and management services for Amtrak's high-speed rail service. The team has one over-riding goal - to make 21st century train travel between Boston and Washington fast, safe and reliable.
>
> The trains and electric locomotives are being manufactured at Bombardier plants in LaPocatiere, Quebec, Plattsburgh, NY and Barre, VT. Bombardier recently expanded its plant in Plattsburgh, due in part to the high-speed rail contract. Plant employment will increase five-fold to over 600 employees. Bombardier has hired local people in all aspects of the operation including assembly, testing, technical services and management. In addition, several out-of-state suppliers have relocated to Plattsburgh to improve service to Bombardier. Fifty-four suppliers from throughout the U.S. are currently involved in the high-speed rail project.
>
> "We are proud to be part of this historic, prestigious project that will revolutionize rail travel on the American continent and create a new industry for future generations," said Bombardier Transit Corporation President Peter Stangl.
>
> Bombardier Transportation is the leading supplier of passenger rail cars in North America and the second largest worldwide. The company provided 195 new Superliner II bi-level coach, full-service dining, lounge, standard and deluxe sleeping cars for Amtrak in the past couple of years. GEC Alsthom is the world's largest builder of railroad equipment and manufacturer of the TGV high-speed train, the world's fastest train, with more than a decade of successful revenue service in six countries in Europe and Asia.

Reaching Another Milestone

> Amtrak has moved another step closer to making high-speed rail service a reality. Recently, Amtrak workers at Sunnyside Yard in New York completed site preparation for a state-of-the-art maintenance and inspection facility for the new trains. Amtrak delivered the site to contractors three months ahead of schedule, while maintaining an outstanding

safety record. The complex project was completed without affecting the on-time performance of trains. The yard was in active use while the site preparation work was in progress. New high-speed train maintenance facilities are also under construction at Amtrak's Ivy City Maintenance Yard in Washington and Southampton Yard in Boston.

More detail is also given in the following *Railway Age* article from April 1998 (*43*).

> The first of Amtrak's Northeast Corridor high speed trainsets are scheduled to arrive late this year at the Transportation Technology Center, Inc., Pueblo, Colo. TTCI, the Association of American Railroads subsidiary that operates the test center under contract to the Federal Railroad Administration, is working with the Bombardier/GEC Alsthom consortium to schedule the necessary testing and commissioning of the high speed equipment before delivery to Amtrak in 1999.
>
> FRA is completing an upgrade to the facility that will allow for high speed testing. The Railroad Test Track (RTT), one of several specialty track loops at the center, has undergone design modifications to accommodate testing of the trainsets up to 165 mph. (The trainsets will operate in the Northeast Corridor at speeds of up to 150 mph.) The ability to test the equipment at TTCI will ensure the safety of operations and the timeliness and efficiency of achieving compliance to Amtrak's specifications, and will minimize disruption to current operations in the NEC.
>
> The upgraded RTT is a 13.5-mile test track with overhead a.c. catenary power. Initially, it will be used for performance and evaluation testing of Amtrak's trainsets, but is expected to eventually function as a key research and test facility for future high speed rail equipment and technologies. Typical test regimes will include high speed stability, energy consumption, electromagnetic interference, high-cant deficiency, acceleration and braking, wheel slip and slide, endurance testing, and exhaust control.
>
> The $8.5 million upgrade to the RTT includes replacing most of the existing 23- year-old softwood crossties with concrete crossties, speed upgrading the catenary system to 60 Hz a.c. at variable voltages of 50, 25, and 12.5 kV, realigning one of the curves for high cant deficiency testing, installing continuously welded rail around the entire loop, and installing a broken rail and open switch point indication system. A small portion of the loop will retain wood crosstie construction consisting of softwood and hardwood ties with conventional cut spikes on some sections and elastic fasteners in others. This section will allow FRA to begin assessment of the performance of high speed rail operations on existing corridors that predominantly use wood crossties.
>
> The successful completion of this upgrade depended upon the support of the railway supply industry as well as FRA funding. Congress challenged FRA to solicit industry support for this project to demonstrate that high speed rail is a viable transportation system for the future. FRA, in turn, asked TCI to coordinate the effort to make up the shortfall of necessary funding to complete the project. Partnerships to support this effort were sought through donations of materials, services, and expertise.

Industry response has been excellent, keeping the upgrade on schedule and within budget. Cost reductions and savings are estimated to exceed $2 million. Major participants include ABC Rail Products Corp., Burlington Northern and Santa Fe, Rocky Mountain Steel Mills (previously CF&I Steel Corp.), Harmon Industries, Inc., Kraiburg of America, Inc., Meridian Aggregates Co., Omni Products, Inc., Pandrol USA, LP, Railway Tie Association, Rocla Concrete Ties, Inc., Union Pacific Railroad, Western Rock Products, and WestPlains Energy.

Appendix B: Information Contained in the Federal Railroad Administration Internet Web Site (*44*)

Maglev Public Comments

Maglev Deployment Program: Federal Register Notice 4910-06-p Department of Transportation, Federal Railroad Administration

Notification of Funds Availability for Magnetic Levitation Transportation Technology Deployment Program ("Maglev Deployment Program")

Agency: Federal Railroad Administration (FRA); Department of Transportation.

Summary: Section 1218 of the Transportation Equity Act for the 21st Century ("TEA 21") establishes a Maglev Deployment Program that authorizes funding for the design, construction, and deployment of one full-scale revenue-service Maglev system, to be sponsored by a State or group of States in a private/public partnership. TEA 21 bases the selection of the system to be deployed on a multi-stage competition. Initially, FRA will select one or more candidate systems to receive funds for preconstruction planning activities; the purpose of this Notice is to solicit applications for this initial competition. Once the preconstruction planning is complete, FRA will select one project to receive financial assistance for final design, engineering, and construction activities.

Eligible Participants: Any State government or any authority designated by one or more State(s).

Deadline For Requests For Applications For Financial Assistance: FRA requests that the completed application packages be returned by November 15, 1998.

Research Projects and Technology

Funds Availability for Research Projects and Technology Advancements Under the Next Generation High-Speed Rail Program:

Documents in HTML format:
Cover Letter, BAA 98-01 Pre-Proposal Preparation, Package, Appendix B, Commerce Business Daily Publication of Pre-Proposal

Cover Letter: (June 18, 1998)
To: All Prospective Offerors

Subject: Broad Agency Announcement No. 98-01, "Funds Availability for Research Projects and Technology Advancements under the Next Generation High-Speed Rail Program"

Your organization is hereby invited to submit a pre-proposal concept paper in response to the subject Broad Agency Announcement (BAA) for the Department of Transportation (DOT), Federal Railroad Administration's Next Generation High-Speed Rail Program. This BAA process allows prospective offerors a high degree of freedom and flexibility in identifying and proposing work or projects in one or more of the following broad areas of research interest to the FRA:

(1) Grade crossing hazard mitigation systems;
(2) Innovative, low cost technologies to improve track and structures;
(3) Advanced train control systems;
(4) Non-electric locomotives and passenger equipment systems; and
(5) Other scientific study, technology adaptation, or demonstration directed toward advancing the state-of-the-art or increasing the knowledge or understanding of high-speed passenger rail service in the U.S.

Federal Assistance Programs for HSGT

Links include: Federal Assistance Programs, Grade Crossing Hazard Elimination, Information on Planning Grants, Magnetic Levitation Program, Next Generation HSGT, Next Generation HSR Technology Development, and Technology Demonstration Projects.

Publications

National Magnetic Levitation Initiative

A series of technical and economic reports undertaken in1990.
Summary
This report presents the findings and recommendations of the National Maglev Initiative, a unique interagency effort of the FRA, the U.S. Army Corp of Engineers, and the Department of Energy, with support from other agencies. The purpose of the report is to recommend future government action regarding Maglev. The recommendation is based on private sector and Government information generated from 1990-1993 concerning the viability of Maglev as an intercity transportation alternative for the U.S. The competition with other modes of travel, the anticipated external benefits such as reduction in pollution and congestion in other modes, and other national-level impacts. The report considers the potential of a new US Maglev system compared with that of alternatives using existing Maglev technology or High-Speed Rail.

High Speed Ground Transportation Policy Outreach

This report was released in November 1995.
Summary
Section 1036 of the Intermodal Surface Transportation Efficiency Act of 1991 required the DOT to establish a national HSGT policy. This policy must include many items. The

Secretary of Transportation was directed to solicit comments form the public on the development of the policy. To do this, a series of outreach meetings were held in 8 cities across the U.S. with more than 500 participants. This report summarizes the outreach effort that ensued from this mandate, and the input received.

Commercial Feasibility Study of High-Speed Ground Transportation

This report was released August 1996.
Summary
This report examines the commercial feasibility of bringing HSGT to well-populated groups of cities (corridors) throughout the United States. In addition the report provides an objective basis for transport policy formulation and planning at the State and Federal levels.

High-Speed Ground Transportation Policy

A draft policy of high-speed ground transportation is expected to be released for comment after the commercial feasibility study is released. In addition to mailing comments to the FRA, a mail box has been established to receive comments electronically. The address for submitting comments on HSGT policy via the Internet is: HSPOLICY@fra.dot.gov.

Additional Links

Links available include: States Prominent in HSGT Development, State and FRA Contacts, Other High Speed Rail and Transportation Web Sites, and International High Speed Rail Development.

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