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**NEW YORK STATE
HIGH-SPEED SURFACE TRANSPORTATION STUDY**

Final Report

Prepared for

**THE NEW YORK STATE
ENERGY RESEARCH AND DEVELOPMENT AUTHORITY**

Project Manager
Richard L. Drake, P.E.

Prepared by

PARSONS BRINCKERHOFF QUADE & DOUGLAS, INC.
in association with

Charles River Associates
URS Consultants, Inc.
Arthur D. Little, Inc.
Harris Miller Miller and Hanson, Inc.
Grumman Aerospace Corporation

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EXECUTIVE SUMMARY

INTRODUCTION

In 1990, New York State Governor Mario M. Cuomo created an interagency task force under the leadership of Lt. Governor Stan Lundine to investigate the potential of high speed ground transportation (HSGT) systems. Building on information from previous agency activities, including consultant efforts contracted by the New York State Energy Research and Development Authority (NYSERDA), the New York State Thruway Authority (NYSTA), and in-house analyses performed by New York State Department of Transportation (NYSDOT), the task force focused on the corridor between New York City and the Niagara Frontier. In December 1991, NYSERDA issued a contract for a study of high speed ground transportation options for New York State.

Study Objective and Scope

The study's objective was to assess potential rights-of-way, ridership, energy and environmental impacts, economic benefits, capital, operating, and maintenance costs, and financial viability of HSGT systems. This study builds upon and supplements previous and on-going HSGT activities conducted by the members of the interagency task force. These activities include:

- Maglev Technical and Economic Feasibility Study (NYSERDA);
- Maglev Demonstration Site Investigation (NYSTA); and
- New York/Massachusetts High Speed Ground Transportation Study (NYSDOT).

This study is intended to verify and refine previous information and analyses and provide supplemental information and insights to be used in determining if additional investigation and activities involving HSGT are desirable for New York State.

HSGT TECHNOLOGIES

This study evaluates HSGT technologies capable of speeds significantly higher than those achieved with the present rail system. Three HSGT categories are used in this study:

Incremental rail improvement (IRI) to the existing rail that includes using the existing rail rights-of-way (ROW), a new, dedicated, non-electrified, grade-separated track, mixed passenger and freight traffic within the same right-of-way, with maximum speeds between 125 mph (200 kph) and 150 mph (250 kph);

Very high-speed rail (VHSR) comprising a high horsepower steel wheel system operating on new, dedicated, electrified track generally built at-grade

but grade-separated with maximum speeds approaching 200 mph (300 kph); and

Maglev, an electrically powered system that uses magnetic forces to elevate and propel vehicles operating on a fully dedicated elevated guideway with maximum speeds of 300 mph (500 kph).

Each technology was compared by evaluating its:

- Performance on existing ROWs of the New York State Thruway and the Empire Rail Corridor;
- Potential passenger and freight market;
- Energy and environmental impacts; and
- Economic benefits.

Volume 2 of the Final Report presents the results of the study in this order:

- Technology Assessment (Section 1);
- Corridor Analysis (Section 2);
- Market and Ridership & Freight Forecasts (Section 3);
- Energy and Environmental Impacts (section 4);
- Construction, Operating and Maintenance Costs (section 5);
- Economic Benefits (Section 6); and
- Financial Assessment (Section 7).

Representative equipment was selected from each speed category to provide parameters for performance simulations. The most advanced rail technology and the Maglev technology closest to commercialization were selected as representatives for the analyses. Combustion engine X2000 (incremental), Transrapid 07 (Maglev) and TGV (VHSR) were the technologies selected. Table S-1 compares the different HSGT technologies.

The reader should note that in an effort to keep the Executive Summary reasonably short and concise, some issues did not receive the detailed attention they rightly deserve. The following is a list of some of those issues where the reader is referred to the main body of the report for the full details:

- Who owns the system?
- Proposed scenarios for entering NYC.
- How and where do we cross the Hudson?
- Electromagnetic Field effects and other environment impacts.
- Right-of-way impacts.
- Thruway realignment to attain maximum speed.
- Guideway switching

Table S-1. Comparison of Baseline Incremental, VHSR, and Maglev Systems.

Characteristics	X2000	TGV	Transrapid	U.S. Maglev
Development status	Vehicles in service*	In revenue service	Demonstration	Concept
Max. design speed	150 mph	200 mph	300 mph	300 mph
Speed attained to date	150 mph	320 mph	250 mph	
Speed calculated on NEW YORK STATE ROW aggressive changes	Max. 150 mph; average 99 mph	Max. 200 mph; average 116 mph	Max 300 mph; average 186 mph	
Dedicated/shared ROW	Existing infrastructure	Dedicated new track required	Dedicated elevated guideway required	Dedicated elevated guideway required
At Grade/Elevated	At grade	At grade	Elevated (15-35 ft) or at grade	Elevated (15-35 ft) or at grade
Grade separated	Grade separated	Grade separated	Grade separated	Grade separated
Max. noise level	N/A	90 dB at speed	95 dB at 270 mph	95 dB at 270 mph assumed
Propulsion	Electric locomotive; diesel adaptable	Electric locomotive	Electric; linear synchronous motor Conventional	Electric; LSM superconducting magnetic (HT)
Rider capacity		376 (TGV) to 1200 (Shinkansen)	100-150	90-150
Minimum curve radius	N/A	13100 ft (186 mph)	7360 ft (at 186 mph)	10,000 ft (400 m) at slow speed
Maximum grade	4%	4%	10%	10%
Superelevation	6"-7"	6"-7"	12 deg	9-15 deg
Tilting capability	yes: 6 deg	no	no	Proposed 9 deg to 12 deg
Radial steering trucks	yes	no	N/A	N/A
Power source	AC-Gas Turbine	AC	DC	DC
Peak power demand		25 kV	10-25 MW	
Power input (MW @ speed)			5.6 MW @ 300 mph to 8 MW @ 322 mph	
Switching	Mechanical operational	Mechanical operational	Mechanical bending switch demonstrated by TR	

* Combustion locomotive development required

Speed Improvement with Different Technologies

Incremental Rail. Incremental rail technologies have been designed to improve the speed and reduce transit times while operating on existing U.S. rail systems. The improved performance is achieved by increasing the horsepower, reducing the weight, introducing compensating tilt in the passenger cars, and using radially steering trucks in some cases. Changing the power-to-weight ratio improves the acceleration capability and tilt technology and reduces the centrifugal forces "felt" by the passengers as the train navigates a curve, thus improving the rider comfort.

Tilting is accomplished in the coach by either passive lateral weight shift similar to a pendulum movement or by active mechanical tilting using accelerometers and hydraulic actuators. The Italian Pendolino and the Spanish TALGO trains are examples of passive tilt technology. The Swedish X2000 and the Canadian LRC are active tilt trains that use accelerometers in the locomotive to activate the tilt mechanism in the passenger cars. According to the manufacturer, ABB Traction Inc., the X2000 equipment can achieve 30 percent faster speeds through curves as a result of tilt and radial steering trucks.

Incremental rail performance improvement is also dependent on the propulsion power-to-weight ratio and the maximum speed. Electrification of the system has a significant positive effect on this ratio, while lower weight has less impact. Combustion locomotives are currently deficient in both top speed and power-to-weight; however, proposed performance specifications, as considered in this study, would significantly improve the performance of the incremental option. The reader should note that the incremental improvement option evaluated in this study describes the performance of combustion locomotives that have been proposed for development, not existing equipment.

VHSR. The first new very-high-speed rail (VHSR), standard-gauge line (*Shinkansen*) was the Tokaido Line, between Tokyo and Osaka that opened for revenue service in 1964 with maximum speeds of 131 mph. Since opening, the *Shinkansen* has carried some 160-million passengers, 30-billion passenger-miles annually, and earns a substantial profit.

In 1981, the French TGV entered revenue service with speeds of 169 mph between Paris and Lyon and has improved speeds further through changes in the locomotive, train weight and systems engineering. Success on the initial line has spurred an aggressive expansion program within France and throughout Europe and abroad. A similar program in Germany introduced the ICE train at operating speeds of 155 mph with plans for increasing speeds.

All the VHSR systems described in this report are currently commercially available and operating in Europe or Japan. For these systems to operate in the United States modest modifications would be required to make them compatible with the U.S. power systems and infrastructure and satisfy the existing safety regulations for rail systems if a waiver from the Federal Railroad Administration cannot be secured.

Maglev. Maglev has been proposed to increase maximum design and operating speeds even further by eliminating the frictional resistance of the vehicle traveling over the guideway and by reducing the vehicle weight. Two concepts have evolved using the fundamental principles of attractive or repulsive magnetic forces. Electromagnetic suspension (EMS) relies on the attraction of the magnets mounted on the vehicle to an iron rail running the length of the guideway. An electrodynamic Maglev system (EDS) suspends the vehicle over the guideway using the repulsive forces of magnetic poles.

In EDS, since the magnetic field must move at a minimum speed to achieve levitation, wheels are usually deployed for slow-speed operations. In either configuration, the gap separating the vehicle and the guideway is controlled through sensors and current regulation to the magnets. Propulsion, in either case, is achieved using a linear synchronous motor integrated into the guideway's design.

Only Maglev systems that are designed and theoretically capable of maintaining speeds of more than 250 mph are discussed and compared, including Germany's Transrapid, Japan's MLU002, and the four systems proposed in the U.S. National Maglev Initiative Concepts.

The Transrapid Maglev system is the most highly developed Maglev in the world today, and the Transrapid 07 (TR07) vehicle currently is being considered for commercial service in the Florida, Pittsburgh, and Cal-Nevada Projects. The TR07 recently has performed numerous certification tests for application in Germany. The TR07 is regularly operated on a 21-mile test track at Emsland in northern Germany. Due to the limitations of this closed-loop track, full-speed operation has not been achieved; however, a record speed of 270 mph was reached in December 1989. The test track provided an opportunity to try both steel and steel/concrete guideway constructions and various elevations above the ground.

In the U.S., a private consortium, Maglev Transit, Inc., has applied for a franchise operation of the Transrapid technology on a 13.5-mile demonstration line connecting Orlando International Airport with International Drive. This franchise application has received many early approvals. In 1991, the U.S. Congress appropriated \$97 million for this project.

U.S. National Maglev Initiative. Alternative Maglev designs developed as part of the U.S. National Maglev Initiative, represent concepts to improve existing Maglev prototypes. Four teams were awarded contracts to develop conceptual designs for a U.S.-based Maglev system to determine if industry could improve significantly on the German or Japanese technologies and reduce the capital costs. These teams were led by Bechtel Corporation, Foster-Miller Corporation, Grumman Aerospace Corporation, and Magneplane, Inc. Three of the proposed concepts are based on superconducting electrodynamic propulsion and levitation but otherwise differ significantly. Alternatively, Grumman's team proposed a superconducting electromagnetic suspension and propulsion system.

Collectively, the U.S. concepts are designed to improve on the capability of either the existing EMS or EDS systems. Without differentiating between these two systems, a number of technological improvements evolved from the work done on the US Maglev concepts. Descriptions of each conceptual design are provided in alphabetical order in Volume II of this report.

ROUTES AND ALIGNMENTS

The corridor used for this study extends from New York City to the Niagara Frontier via Albany. It passes through the Hudson Valley, the Capital District, the Mohawk Valley to Syracuse, Rochester and Buffalo and the Niagara Frontier. Table S-2 shows the initial station areas incorporated into the overall corridor alignment. These stations were the theoretical locations used for subsequent calculations and analyses.

Table S-2. Alternative Station Locations for Major Metropolitan Areas.

Metropolitan Area	Alternative Station Location
New York City	Pennsylvania Station Sunnyside Yard Secaucus, New Jersey Grand Central Terminal
Northwestern Suburbs	Tarrytown (MNCR) Tarrytown (Van Wart) Tarrytown New Rochelle
Mid-Hudson Area	Poughkeepsie Kingston Newburgh
Albany	Rensselaer, East Street Everett Road/I-90 Guilderland Broadway/Livingston Avenue
Utica	CBD Main Street NYS Thruway/I-70 Intersection
Syracuse	East Syracuse Manilius Road NYS Thruway/I-81 Carousel Mall
Rochester	CBD Central Avenue West Henrietta Ridgeland
Buffalo	Depew, Dick Road CBD Exchange/Hamburg Williamsville Main/LaSalle
Niagara Falls	Hyde Park Boulevard Whirlpool Street

New York City Access

The location of alternative routes into a New York City terminal from the northwestern suburbs was given special attention. The identification of new alignments or adjustments to existing alignments in this area is difficult due to existing infrastructure and development and existing transportation corridors within a 40-mile radius of mid-Manhattan.

The evaluation of possible terminals considered existing facilities, regional intercity connection, and local intermodal connectivity and economic potential. Four terminal locations provide access to New York City: Pennsylvania Station and the vicinity (CBD); Grand Central Terminal (CBD); Sunnyside Yards (Queens); and Secaucus, NJ. Each of the locations has advantages and disadvantages in terms of capacity, expansion capability and accessibility for travelers.

Alternative access routes to these locations, whether from the Thruway corridor or rail corridor, ultimately require some use of the Metro-North or Amtrak ROW to the Manhattan and Queens sites. A highway access alternative is available for access to the Secaucus terminal site. Given these station locations, access routes alternatives included:

- Using the Thruway and connecting to the rail access to Pennsylvania Station;
- Using the existing rail lines into Pennsylvania Station;
- Using the existing rail lines into Sunnyside Yards; and
- Using highway ROW on the west side of the Hudson to a station in Secaucus, NJ where a path system transfer is required for Manhattan access.

The Pennsylvania Station location was determined to be the best location for the HSGT terminal because:

- Its mid-town location is convenient to many Manhattan destinations;
- There are subway connections for cross-town destinations; and
- Excellent regional and national rail access is provided by New Jersey Transit, the Long Island Rail Road and Amtrak.

Congestion and station capacity suggest that expansion adjacent to the station may be required and will require additional study.

The Grand Central Terminal does not have comparable access to the regional transportation network. Therefore, its use would not allow direct transfers to intercity connections along the Northeast Corridor. Sunnyside Yards, an existing rail maintenance facility and storage yard in Queens, is connected directly to Pennsylvania Station through Amtrak. Developing a transportation center here that would link the LIRR, Amtrak and the New Jersey Transit has been considered.

The Secaucus station site lies east of and adjacent to the New Jersey Turnpike, and lines of New Jersey Transit and Amtrak's NEC. While a proposed transfer station would allow direct connections to Pennsylvania Station, connections to most other NJT, LIRR and Metro-North systems would require a second transfer.

Hudson River Crossings

Access to New York City is limited by the number and condition of the existing bridges across the Hudson River. Whatever access route into New York City is chosen, crossing the Hudson River will be a major piece of engineering, with substantial costs. As part of its capital improvements plan, Metro-North investigated various alternatives for a new rail crossing of the Hudson River.¹ In addition to the river crossings, all the alternatives involve new ROWs including new bridges and, in a few cases, additional tunnels. For some alternatives, the new construction may involve the use of aerial structures, e.g., alternatives that use portions of the existing I-287 ROW. Eleven preliminary alternatives initially identified were reduced to two candidates:

- A new high-level two-track cable-stayed bridge with a main span of 1170 feet with 500-foot back spans; providing a vertical clearance of 139 feet above mean high water to match the existing Tappan Zee Bridge; and
- An immersed tube tunnel in the vicinity of the Tappan Zee Bridge.

The roadway on the Tappan Zee Bridge was recently rebuilt to provide seven lanes, 84 feet wide. Removing lanes to accommodate the high-speed guideway or rail at the deck level was considered but eliminated due to structural limitations.

While construction methods and types of structures would use conventional techniques, working in a relatively crowded suburban environment will present a challenge. For alternatives that involve construction along the existing ROW, the impact on the existing highway and rail traffic must be minimized.

System Performance and Alignment Modifications

The Empire rail corridor and the New York State Thruway were the two ROWs alignments evaluated for implementation of incremental rail, VHSR and Maglev. The primary focus of the corridor evaluation was an assessment of existing alignments and judicious straightening of speed-limiting curves to determine the level of performance achievable by HSGT systems.

Field investigations reviewed and supplemented existing data that were compiled into an "Existing Conditions Database" for each corridor. Data include characteristics and attributes by milepost; property ownership; county; existing railroad and highway facilities; horizontal

¹ Feasibility and Cost Benefit Study of Cross Hudson and Stewart Airport Rail Links: Preliminary Conceptual Alternatives Report, December 1990; submitted by Parsons Brinckerhoff to Metro-North Commuter Railroad.

and vertical curvature; grades; grade-separated crossings; ROW width; potential restrictions; and current adjacent land uses. This extensive data base established the existing alignments and subsequent modifications to the curves in the performance simulations for both VHSR and Maglev.

Using a train performance calculator (TPC) model, simulations for each of the representative technologies were run using the existing alignments to establish a baseline performance. For the VHSR and Maglev options, the baseline simulations then were used to identify segments containing individual or groups of speed-limit curves where straightening curves could improve the speeds. Two modifications to the baseline conditions were made: a "moderate" realignment and an "aggressive" realignment.

Each step in the alignment modification assumed greater liberties in the degree of departure from the existing ROW. The moderate realignment avoided residential, commercial and other developed areas, avoided sensitive areas such as rivers, and wetlands, and costly construction through difficult terrain. Large cuts or fills and encroachments into rivers were generally avoided.

The aggressive realignment involved modifying more curves, and accordingly was less restrained. A relatively aggressive use of tunneling and major earthworks was assumed accepting certain environmental and social impacts and higher construction costs when running time improved. Multiple Thruway and river crossings were assumed in the aggressive case, as necessary. The aggressive configuration represents an outer limit of acceptable realignment while maintaining maximum use of existing ROWs within urban areas and environmentally sensitive areas. With progression from moderate to aggressive, more curves over a given limiting segment were modified to improve performance.

A total of seven alignment options were investigated in this study. A train performance calculator (TPC) was used to estimate the station-to-station performance; i.e. running times and achievable speeds of the various options. The options analyzed are:

Maglev

Four alignment options were explored:

Baseline (TPC-2) - This option incorporates a Maglev system using tilt equipped vehicles, totally within the limits of the NYSTA's ROW;

Moderate (TPC-4) - This analysis is similar to the Baseline but incorporates an alignment which moderately deviates outside the existing NYSTA's ROW, with minimal impacts, at certain locations;

Moderate (TPC-4a) - This option is similar to Moderate (TPC 4) except that it does not incorporate tilt-bodied equipment; and

Aggressive (TPC-6) - This analysis is similar to the Baseline but investigates an alignment that aggressively deviates from the existing NYSTA's ROW, with a correspondingly higher level of impact from the Moderate scenarios.

VHSR

Three alignment options were explored:

Baseline (TPC-1) - This option analyzes the VHSR technology within the existing Empire Corridor including the Metropolitan Transportation Authority's (MTA) Metro-North Commuter Railroad (MNCR) NYC to Poughkeepsie corridor and Conrail's ROW from Poughkeepsie to Buffalo via Albany;

Moderate (TPC-3) - This analysis is similar to the Baseline option except that it investigates moderately deviating from the ROW of the Empire Corridor with minimal impacts; and

Aggressive (TPC-5) - This option is similar to the Baseline but assesses an aggressive deviation outside of the Empire Corridor's ROW, with larger consequences than the Moderate option.

Incremental HSR

This option analyzes an incremental HSR (TPC-7) application on new dedicated track within the ROW of the Empire Corridor.

The performance of the incremental rail option reflects the most optimistic assumptions regarding the development of more powerful non-electric locomotives and waivers from the Federal Railroad Administration on the maximum allowable speeds and underbalance on the existing rail corridor. It also assumes that appropriate signaling and automatic train controls operations are in place, and appropriate grade-separations are made. The input characteristics of the "modified X2000" are based on a higher horsepower, gas turbine-electric locomotive capable of a maximum speed of 150 mph. This equipment is not yet available but is considered feasible for a non-electrified section of track.

Travel Times

Travel-time analyses of the various HSGT alignment TPC options are shown in Table S-3. The travel times shown in Table S-3 were used as input to the passenger demand forecasting model. These times included stops at each city along the corridor assumed to provide maximum frequency of service and thereby maximum ridership. Faster times would result from express service or skipped stops. For some city pairs, the faster trip times for express service may provide additional ridership. Express trip times for selected city pairs are shown in Table S-4.

Table S-3. Results of Performance Simulations Showing Improved Speeds with Realigned Curves on Each ROW.

Run No.	Type	Average Speed (mph)	Trip Time** (Hrs./min.)
Performance Calculations-- Incremental			
Existing rail alignment	Combustion X2000	99	4:40
Performance Calculations-- VHSR			
TPC-1 - Baseline	TGV	86	5:23
TPC-3 - Moderate rail	TGV	102	4:34
TPC-5 - Aggressive rail	TGV	116	4:00
Performance Calculations-- Maglev			
TPC-2 - Baseline (with tilt)	TR07	158	2:52
TPC-4 - Moderate (with tilt)	TR07	174	2:36
TPC-4a - Moderate (without tilt)	TR07	155	2:55
TPC-6 - Aggressive (with tilt)	TR07	187	2:25

**Niagara Falls to Pennsylvania Station - Including stops at each major city. Faster times are available for express service, but the number of passengers may not be as high, depending on the city-pair considered.

Table S-4. Estimate of Maglev Express Trip Times Savings.

TPC	New York City to Albany Express	Albany to Buffalo Express	New York City to Buffalo Express
2	1:00	1:06	2:08
4	0:57	0:56	1:55
6	0:50	0:53	1:45

Regional Route Extensions

The potential for expanding the revenue potential of the high-speed intercity market included a qualitative assessment of these feasible route extensions to encompass the Northeast Region:

- West from Buffalo to Cleveland and Chicago along I-90;
- East from Albany to Boston along I-90; and
- South from New York City to Washington, D.C.

These alternatives were technically feasible as available ROW; horizontal and vertical curvature characteristics of these routes appear as favorable as or better than those on the New York State Thruway. Applying average speeds from the New York State alignment performance simulations, the travel time from Buffalo to Chicago could range from four and one-half hours to more than five hours, depending on station stops and alignment details. Parts of this alignment were investigated for HSGT implementation previously, and more details on the ROW and performance are found in the Blueprint Detroit to Chicago Study.²

The Northeast Corridor route, Boston - New York City - Washington, D.C., passes through highly developed urban areas, with stations generally located in the city centers with little additional space for new trackage or dedicated guideway system without removing some of the existing track and displacing adjacent landowners. The rail corridor from Washington, D.C. to New York City operates a full complement of local and intercity passenger and freight rail lines requiring complex logistics and coordination of planning, safety, and design. In addition, this route has several major physical constraints including small-diameter tunnels with limiting curves in Baltimore and under the Hudson River. A combination of rail and highway ROWs would provide the best alignment to the south of New York City. Travel times for VHSR and Maglev on this route would be two hours and under one and one-half hours, respectively, depending on the number of station stops and alignment details. The fastest travel time currently provided by the Amtrak Metroliner service on existing track is 2 hours and 40 minutes.

An extension from Albany to Boston using the I-90 corridor also appears feasible, although more rugged terrain along part of the corridor may limit speeds or require additional grade-leveling earthworks. Travel times from Albany to Boston are estimated at less than two hours for VHSR and about one hour and fifteen minutes for Maglev. This corridor is the subject of a more detailed investigation of the feasibility and performance capabilities of VHSR and Maglev.³

The regional extensions to major cities in the Northeast Region significantly affect revenue projections for HSGT. Order-of-magnitude estimates of the ridership demand for each extension were made in the passenger market forecast.

² High Speed Rail Feasibility Study performed by the State of Michigan, 1992.

³ Massachusetts/New York High-Speed Surface Transportation Study by EBASCO Infrastructure.

MARKET FORECASTING

Market forecasting is divided into passenger demand and freight demand. The ridership and passenger revenue forecasts for a HSGT focus on intercity service in the New York City-Albany-Buffalo corridor and order-of-magnitude estimates of the ridership gains afforded by regional extensions west to Chicago, east to Boston, and south to Washington, D.C. The freight market is evaluated similarly, and it is assumed that the HSGT system is part of a regional network.

Ridership Forecasting Assumptions

To develop projections of HSGT ridership and revenue, a file of intercity trips by existing modes made in the base year was assembled. To accomplish this task, air origin/destination (O/D) volumes (for "true" O/D trips) were obtained from the 10 percent sample collected by the Federal Aviation Administration. Annual rail (Amtrak) volumes on a station-to-station basis were obtained from the New York State Department of Transportation which tabulates this information from data supplied by Amtrak. Annual auto O/D volumes were obtained from an intercity travel demand model developed by the Volpe National Transportation Systems Center (VNTSC) that relates auto travel between city pairs to socioeconomic and other descriptors of each city pair. This approach is necessary because for some O/D pairs, multiple highway paths are possible.

In addition to the base year (1991) O/D volume information, it was necessary to specify various HSGT levels of service. The following was used to forecast ridership for incremental rail improvements, VHSR or Maglev:

- Two-minute stops at each station;
- Incremental rail traveling on the existing ROW, with non-electric equipment, with tilt capability, traveling at an average speed of approximately 100 mph;
- A VHSR system traveling on an aggressively realigned rail corridor;
- A Maglev system traveling on an "aggressively" realigned New York State Thruway ROW with an average speed of 187 mph;
- HSGT fares set at a point of maximum revenue;
- Business and non-business fares priced equally; and
- Service provided at half-hour intervals during peak travel periods and at hourly intervals during other times over an 18-hour day.

Ridership and Revenues

Forecasts for diverting travelers from the existing modes to either incremental rail, VHSR or Maglev were made using fares ranging from a low of existing rail fare to a high of existing

air fare. The approximate point of maximum system farebox revenue was then determined. For Maglev, this was found to be a fare equivalent to roughly 220% that of existing rail, while for the incremental improvement and VHSR options this was found to be approximately equivalent to 300% of existing rail fare.

In all cases the greatest diversion, in terms of absolute numbers, comes from those traveling now by automobile, followed by air travelers, then rail. In terms of percentage of travelers diverted from existing modes, Maglev would capture 84.7% of existing air travel, 47.8% of rail and 9% of auto travel. For the lower speed VHSR and incremental improvement options the percentage of travelers diverted from air is 35.5%, with a 20.8% diversion from rail and 5.6% from auto. As travel times decrease, there is a higher diversion from the air mode to Maglev.

Auto travelers were found to be extremely sensitive to the combined aspects of fare and travel time. For Maglev a reduction in fare from 300% of existing rail to 220% increased the ridership diversion from auto by 50% while for the lower speed incremental option a reduction from 300% to 100% of existing rail fare only increased the diversion from the auto mode by 29%.

Figure S-1. Comparison of Forecasts for Three HSGT Alternatives.

Assuming the system does not extend beyond the State boundaries, it is estimated that more than 5.2 million HSGT trips on Maglev would be made annually in the year 2010, with cross-state trip times of 2.5 hours. Such a system can generate passenger revenues of \$497 million dollars, assuming fares equivalent to 220% existing (1993) rail fares. Sensitivity analyses indicate this fare structure maximizes revenues with a drop-off when fares are raised or lowered.

A New York State HSGT system implemented with the lower speed options would produce lower ridership and revenue. At a fare structure producing maximized revenue the ridership on the aggressive VHSR system was forecasted to be 3.9 million passengers producing revenues of \$343 million. For the incremental option, passenger ridership was forecasted at 3.5 million with revenues of \$297 million.

The reader should note that alternative fare price structures, common in the airline industry, offering a variety of fares differentiated by time of day, business/non-business, and the number of days between ticket purchase and departure, would produce different ridership volumes. Further increases in system revenue may also be possible with such an alternative fare structure. It is also quite likely that a fare structure designed to maximize system revenue would not be determined to be appropriate or in the public interest, particularly in the case of incremental rail improvement. Such issues are beyond the scope of this evaluation of the technical feasibility, market and revenue potential of the options.

Regional Extensions

The ridership projections presented in Figure 5-1 show trips for passengers whose travel origins and terminations are within the New York State "Empire Corridor." This Buffalo-Albany-New York City transportation corridor has historically been at the center of a regional network extending north to Montreal and Toronto, south to Washington D.C., west to Cleveland and Chicago, and east to Boston.

Projections of total ridership in the corridor increase significantly if it is assumed that passengers are able to extend their travel to regional cities connected to a common HSGT network. Because only a portion of these trips are within the New York State corridor, it is useful to express this increased ridership both in terms of trips and passenger miles within and outside of the New York corridor. Table S-5 shows ridership on the New York State corridor that could develop if the HSGT (Maglev) system is assumed to have regional extensions with trip times previously described.

For a regional HSGT system, extending south to Washington, D.C., east to Boston from Albany, and west from Buffalo to Chicago, it has been estimated that some 20 million trips would be made in the year 2010. These projections may be somewhat conservative in that only trips whose origin or destination is a city within the New York State corridor and a major city at the terminus of a regional extension are considered. For example, trips that terminate in cities between Albany, NY and Boston, MA, such as Springfield and Worcester, MA, have not been included.

Table S-5. 1991 HSGT Passenger Miles -- Summary.

Corridor	Total HSGT Ridership	Passenger-Miles		
		Inside NY State	Outside NY State	Total
New York State	4,800,000	1,057,000,000	0	1,057,000,000
Western Extension	2,400,000	850,000,000	1,065,000,000	1,915,000,000
Southern Extension	6,600,000	228,000,000	1,050,000,000	1,278,000,000
Eastern Extension	6,200,000	998,000,000	1,558,000,000	2,556,000,000
Total	20,000,000	3,133,000,000	3,673,000,000	6,806,000,000

SOURCE: Charles River Associates, 1993.

Sensitivity Analyses

To determine how ridership and passenger revenues may vary given alternative (input) assumptions, sensitivity analyses were performed by varying five parameters that commonly influence HSGT demand. Figure S-2 illustrates the variation in ridership as the factors are changed. The analysis shows that ridership is most sensitive to fare. If HSGT fares are reduced to current rail rates, HSGT ridership increases by 108.8 percent. However, in this instance, passenger revenues decline from the base case by nearly 23 percent. If HSGT fares are set equivalent to the higher air fares, HSGT ridership declines 27.9 percent while revenues increase by only 2.1 percent. Since with higher fares, HSGT revenues barely increase, this indicates that the HSGT fares assumed in the base case (three times current rail fares) are very near the revenue-maximizing point.

Travel time was found to be the second most important factor influencing ridership. Since the base case uses the aggressive Maglev travel times, any other test of HSGT travel times reflects slower speeds and reduced ridership. Thus under the "moderate" VHSR scenario, HSGT ridership is estimated to decrease 27.5 percent while passenger revenues decrease 35.4 percent compared to the base case. Under the slightly better aggressive VHSR scenario, HSGT riders decline 23.1 percent while passenger revenues decline 29.9 percent.

Table S-6 shows the sensitivity of revenue to changes in HSGT fares, frequency, travel times, access/egress times, and terminal processing times. While the changes resulting from variables other than fare and travel time are predictable, the magnitudes of change are not as large as fare and travel times.

Figure S-2. HSGT Sensitivity Analyses Results.

Table S-6. Sensitivity Analysis of HSGT Ridership and Revenue.

Factor	HSGT Assumptions	Ridership Change (%)	Revenue Change (%)
Base Case	Base Case	0	0
Fare	Rail (existing)	+108.8	-22.8
	Air	-27.9	+2.1
Travel Time	Moderate VHRSR	-27.5	-35.4
	Aggressive VHRSR	23.1	-29.9
Frequency	1/2 hour	+3.5	+2.8
	1-2 hours	-10.6	-10.4
Access/Egress	+20 percent	-5.3	-5.7
	-20 percent	+5.6	+6.0
Terminal Time	Air	-2.8	-3.2
	-20 percent	+2.1	+2.4

FREIGHT FORECASTS

Implementing a HSGT system would allow for the rapid transportation of certain types of freight. The most likely market segment that could be attracted by a HSGT system would be small-lot time-sensitive freight. This is one of the fastest growing segments of the freight transportation market, and it is expected to continue to grow at a rate exceeding other freight markets.

Expedited freight can be disaggregated into overnight service and deferred service. Overnight service involves a late afternoon/evening pick-up with delivery assured the following business day - at a premium price. This market sector has some \$13 billion in revenue nationally in 1991; a volume of more than 7 billion pounds on 650 million shipments; and an average annual revenue growth of 6.2 percent from 1989 to 1991.

Deferred service offers expedited delivery within two to three business days to shippers who require quick transport, but who are reluctant to pay a premium price for guaranteed overnight delivery. Deferred service is six times larger than the overnight market with a national revenue of almost \$15 billion for 1991; more than 42 billion pounds of volume on 2.5 billion shipments; and revenue growth averaging 5.1 percent over the same period.

This study estimated annual regional freight revenues the various HSGT systems could potentially capture. Since implementation of an incremental HSR system would not be of the magnitude needed to stimulate interest by freight shippers, and since the improvements are on freight corridors already providing competitive service, this analysis does not investigate incremental HSR.

Freight Revenues

A model was used to estimate HSGT revenues and tonnages based on varying fares and to determine the price at which a shipment would be diverted from an existing service to HSGT. The results of the fare sensitivity for the different freight modes and the total revenues anticipated from an expedited freight market are shown in Table S-7. The largest revenue producer would be express freight at \$132 million annual revenue out of \$231 million total annual revenue from all forms of expedited freight.

These revenues assume that the New York State HSGT system is a part of a regional intermodal network connecting all major cities east of Chicago and north of Washington, D.C., and that freight handling, freight terminals, and sorting facilities are in place and stations are appropriately located.

Table S-7. Annual Regional Freight Revenue Forecasts by Mode and Rate.

Category of Freight	Regional Revenues	Corresponding Rates
Express	\$132 million	\$0.45/lb.
Surface	\$25 million	\$0.65/lb.
"Air" Cargo	\$45 million	\$1.40/lb.
Overnight Air		
Less Than Truck Load	\$29 million	\$0.15/lb.
Total	\$231 million	

ENVIRONMENTAL IMPACTS AND BENEFITS

Constructing a new transportation infrastructure across New York State and the region will produce both environmental impacts and benefits. The impacts can be mitigated through careful planning, and design, during the environmental permitting process that will be required for a new cross-state transportation system.

Some environmental benefits that may be realized if a HSGT system is implemented include:

- Significant reduction in air emissions, resulting in improved air quality;
- Increased fuel efficiency; and
- Reduced highway and airport development that may reduce long-term ROW acquisition, local noise, and air emissions.

Pollution Emissions

One of the potential benefits to be derived from the introduction of a HSGT system in New York State is the reduction in pollution emissions and fuel efficiency compared with the existing air and automobile projections. By diverting passengers from air and automobile as projected in the demand forecast, there will be significant reduction in air pollutant emissions from both VHSR and Maglev. Comparing the estimate of emission reductions resulting from VHSR or Maglev, VHSR, operating at lower speeds, consumes less electricity, contributing slightly more towards cleaner air. In addition, carbon monoxide and tire particulate release to the atmosphere are reduced with diversion from auto to VHSR or Maglev.

The term "externality cost" is used in this study to mean what economists refer to as unpaid "damages" caused by the combustion of fossil fuels. Variables such as fuel type, pollution controls, health risk, population exposed, discount rate and other factors affect the unpaid environmental cost; due to the variables, the "externality costs" per ton of specific emissions may vary from region to region or state to state.

This Report reflects recently (1992) evaluated⁴ externality values for electrical power plant generation used in comparing power plant alternatives such as hydro, coal, oil and natural gas energy sources in New York State. They are used to help quantify the value, otherwise not captured, of alternative, electrified transportation technologies considered in this study. Table S-8 shows the emission reductions and the associated value of these reductions that would result from the implementation of the various HSGT options in New York State.

Table S-8. Emissions Reductions for VHSR and Maglev with Resulting Savings from Passenger Diversions (New York-Intrastate Ridership Only).

	Tons per year saved		Externality Values	Maglev	TGV
Pollutant	Maglev	TGV	\$/ton	\$/Savings	\$/Savings
SO ₂	23	32	\$1,324	\$30,452	\$42,368
NO _x	323	442	6,320	2,041,360	2,793,440
CO ₂	110,185	185,094	25	2,754,625	4,602,350
VOC	99	136	3,850	381,150	523,600
TSP	36	50	3,850	138,600	192,500
Total Cost Savings:				\$5,346,187	\$8,154,258

Regional Environmental Implications

Airborne emissions do not recognize political boundaries. Therefore regional residents would benefit from a reduction in pollutants that would result from the implementation of a New York State HSGT system.

The magnitude of air quality improvement is a function of the number of passenger miles diverted from the air and auto transportation modes to a HSGT system. Ridership in the corridor is maximized with a system that has regional extensions. Ridership projections show that a system with regional extensions will attract more than five times the passenger miles than a New York State stand-alone system. This implies that a system with regional extensions would produce five times the air quality benefits of a New York intra-state-only system.

Energy Requirements

The estimates for energy requirements for each system are based on performance simulations of equipment with characteristics similar to the X2000, TGV and Transrapid 07. In each run,

⁴ Hydro-Quebec Economic Study, New York State Energy Office.

stops were made at stations located in each major metropolitan area. Acceleration and deceleration for stations and speed-limiting curves assumed maximum allowable rates. No attempts were made to optimize operations for energy purposes.

TGV and Maglev estimates are given in Table S-9 for the most aggressively realigned route of the rail and highway alignments, respectively. In each run, stops were made at each major metropolitan area and acceleration and deceleration for stations and speed-limiting curves assumed maximum allowable rates. Data from simulation runs indicate that energy needed for the moderate realigned configuration was lower because the maximum speed was maintained over a greater portion of the trip. The Maglev runs suggest that tilting is beneficial in terms of energy consumption, due to the lower deceleration necessary in curves.

Table S-9. Estimate of Energy Requirements from Simulation Runs.

Run No.	Alignment Condition	Max. Speed (mph)	Avg. Speed (mph)	Specific Energy kW/Seat-Mile ⁵	Total Energy Output BTU/Seat-Mile
X2000	Existing Rail	150	99	0.101	2,296
1 VHSR	Existing Rail	200	96.2	0.105	1,086
3 VHSR	Moderately realigned	200	101.8	0.107	1,107
5 VHSR	Aggressively realigned	200	116.1	0.107	1,107
2 Maglev	Existing Thruway	300	158.1	0.119	1,230
4 Maglev	Moderately realigned	300	173.8	0.126	1,303
4a Maglev	Moderately realigned	300	154.8	0.111	1,148
6 Maglev	Aggressively realigned	300	186.9	0.131	1,354
Automobile 1.6 passenger/car	--	--	55	--	2,182
Air (75 % occupancy)	--	--	--	--	5,346

⁵ Excludes power plant efficiency and combustion engine efficiency.

In the case of the X2000 option an on-board distillate fuel is used to power the locomotive. This equipment does not exist; therefore, the characteristics of a state-of-the-art gas turbine engine suitable for the service was used to provide an order-of-magnitude estimate of energy efficiency.

ECONOMIC AND FINANCIAL ANALYSES

Capital and O&M Costs of VHSR and Maglev

Estimates for capital cost and operations and maintenance (O&M) costs are shown in Table S-10. The cost estimates are based on some differences in infrastructure required for operating each technology. For example, VHSR estimates assume on-line stations, whereas Maglev estimates assume off-line stations that necessitate switches to allow vehicles to exit and re-enter the guideway from the stations. The VHSR estimates assume mostly at-grade track, whereas the Maglev guideway constructed along the Thruway assumes an elevated guideway the entire length of the corridor. Closer examination of the Thruway ROW and frequency of overpasses and interchanges could reveal segments where a near-grade guideway could be constructed without concern for vertical curve constraints. This would help to reduce total system costs.

Other cost-estimating assumptions are:

- Dual track or guideway;
- On-line VHSR stations/off-line Maglev stations;
- Two termini for night storage of equipment;
- Classification of bridges and tunnels, as minor or major structures or special;
- Coordination with ROW data from the corridor analysis;
- Fleet size based on 11 vehicles or train sets per day in each direction;
- Maglev guideway design proposed by Parsons Brinckerhoff in the National Maglev Initiative System Concept Definition;
- Classification of terrain according to grade, and land use;
- Reconstruction costs including civil demolition, highway relocation and reconstruction, utility relocation and environmental mitigation costs;
- Contingencies; and
- Interest during construction.

The cost of incremental rail improvements consistent with the level of performance described in this report is estimated at \$1.5 billion. Cost estimates for the incremental rail improvements are order-of-magnitude estimates shown in 1992 dollars based on costs developed in 1989. The capital cost improvements for incremental rail are taken from the Draft Local and State Railroad Tax Council Report (1989)⁶. Rolling stock costs range from \$13 million to \$18 million per train, based on recent data for the X2000.

⁶ New York State Department of Transportation, 1989, "Local and State Railroad Tax Council Report" (draft).

Table S-10 Summary of Costs and Benefits for Representative Technologies of Various Speed Categories.

Technology	Capital Cost	O&M Cost	Temporary Jobs	Permanent Jobs
Incremental rail	\$1-2 Billion	N/A	Not calculated	Not Calculated
VHSR	\$7 Billion	\$97 Million	90,000	30,000
Maglev	\$17 Billion	\$120 Million	190,000	37,000

The estimated \$7 billion in construction costs for the VHSR intrastate system includes all the capital costs of construction, ROW acquisition, rolling stock, 20 percent contingencies and interest during construction. The O&M costs include approximately \$46 million a year for labor or personnel costs, and \$51 million a year for materials.

Constructing a new Maglev system from New York City to Niagara Falls is estimated to cost more than \$17 billion including the costs of construction, rolling stock, engineering, and management, with project contingencies at 20 percent. This Maglev system is estimated to cost more than \$100 million annually to operate and maintain, consisting of more than \$39 million a year in personnel and administrative costs, and \$61 million a year in materials, maintenance-of-way (MOW), energy and vehicle maintenance costs.

Economic Benefits

Building and operating a HSGT system in New York State will generate substantive economic benefits to the region as a whole, particularly in the form of indirect economic benefits or spin-offs from capital and O&M dollars. The indirect benefits include permanent and temporary jobs, time savings from reducing travel time and increased productivity, reduced accidents and fatalities, and environmental benefits of cleaner air and better fuel economy.

Jobs

Implementing a Maglev system in New York State may create 190,000 temporary jobs during the construction period, increase State output by \$25 billion and enhance household earnings by more than \$7.8 billion over a twenty year period. Operating and maintaining a Maglev system has the potential to create more than 37,000 person-years of employment, increasing State output by more than \$4.3 billion, and enhancing household earnings \$1.5 billion. In addition, there may be significant technological spin-offs from developing a Maglev system.

Constructing the VHSR system has the potential to generate about 90,000 temporary construction jobs throughout the State, raising State output by more than \$12 billion and increasing household earnings more than \$3.6 billion. Operating and maintaining the HSR,

steel wheel alternative has the potential of generating more than 30,000 person years of employment, raising State output \$3.5 billion and increasing household earnings by more than \$1.2 billion over a twenty year period.

Both VHSR and Maglev systems are predicted to have a positive effect on property values and land development around the station areas, although this type of economic development will not occur with the same level of intensity as that associated with many transit stations. Existing land-use conditions, growth-management policies, zoning ordinances and other governmental planning policies will determine to a large extent the form and range of such influence.

Travel Cost Savings

Comparing the total costs of travel, including the sum of the line haul costs (the time spent in a vehicle or on the aircraft), access and egress costs, all other out-of-pocket costs, as well as the costs of time spent traveling by those who would divert to VHSR/Maglev, reveals that for business trips, air travelers would experience the greatest total travel cost savings; rail travelers would experience lower savings; and automobile users would not save at all by diverting to VHSR/Maglev, but would trade higher total travel costs for reduced trip time and convenience.

Considering the total travel time that includes line haul, access and egress times, as well as waiting times at stations or airports, highest total time savings using a VHSR/Maglev system would be experienced by passengers who otherwise would travel by conventional rail.

For non-business trips, total travel cost savings would only be experienced by existing air travelers diverting to VHSR/Maglev; all other travelers would face higher travel costs by diverting, on a per-trip basis.

Looking at only the passenger trips diverted to VHSR/Maglev that would result in net travel savings for each passenger, the total annual value of passenger time saved amounts to \$90 million in 1993 dollars; about \$68 million is accounted for by business trips and close to \$24 million represents non-business trips.

For all trips, the total annual travel cost savings for diverted business passengers amount to \$16.7 million, representing more than \$51 million in annual travel cost savings for diverted air passengers; \$9.7 million in savings for diverted rail passengers; and net cost increases of more than \$39 million for passenger car users who need their autos at their destinations and about \$5 million for car users who do not.

Impact of Changes in Travel

By diverting to VHSR/Maglev, more than 2 million automobile trips can be avoided annually, consisting of nearly two-thirds non-business trips.

Despite possible reactions from the commercial air carrier industry, it is estimated that from 17,000 to 34,000 aircraft flights can be avoided annually by introducing Maglev in New York State by 2010, assuming that the current mix of aircraft size and capacity is maintained.

Implementing a Maglev system is estimated to reduce statewide transportation fuel consumption 17.4 million gallons annually by 2010; 12.6 million gallons from eliminated air trips; 4.6 million from diverted auto trips; and the remainder from existing rail trips.

By diverting passenger automobile users to HSGT, more than 200 automobile accidents are estimated to be avoided annually in 2010, resulting in 27 fewer fatalities due to accidents on average, and accident savings of \$3.1 million annually.

Financing

With fares set at rates to achieve maximum revenue, HSR and Maglev systems will raise enough revenues to cover annual O&M costs. However, the annual revenues raised from fares for a system limited to New York State will not cover the capital costs.

Given the significant financial investment associated with both HSR and Maglev, New York State must seek significant support from the Federal government and the private sector. This partnership is crucial to support the extensive research and development associated with prototyping new technology, guarantee financial success, and manage construction and operation of the world's first Maglev system or implement a true HSR project in the United States.

A strong Federal partnership is usual for other forms of public transportation where capital assistance is among the most common methods for government to facilitate the development of needed services. Airports, for example, are usually developed by the public sector for use by private air carriers. Public transit systems receive significant public funding for their capital needs as well as on-going operating costs. Amtrak relies on public support for virtually all its capital need and a portion of ongoing operations. Northeast Corridor improvements between Boston and Washington were and continue to be paid for by 100 percent Federal funding. Finally, the National Highway System is usually improved with public funding, with the Federal government paying 80 percent for most regional improvements on the Interstate Highway system.

At the Federal level, there is growing momentum to support development of HSGT transportation network. Thanks to Senator Moynihan of New York, the Intermodal Surface Transportation Efficiency Act of 1991 reflects the growing interest in HSGT by authorizing \$800 million for research and development of Maglev and HSR. In 1993, the Clinton administration proposed a \$1.3 billion National High Speed Railroad Development Program.

In November 1993 New York State's governor Mario M. Cuomo and Lt. Governor Stan Lundine announced a Proposal for High Speed Ground Transportation in the State of New York. This proposal identified a 75 percent Federal contribution to New York's HSR improvement projects and Maglev development initiative. This contribution is equivalent to

Federal support of other modes of transportation at a level already authorized for the Federal Maglev demonstration project.

New York State is in an excellent position to take immediate advantage of funds made available through any Federal High Speed Rail program. In fact, if the criterion in the Proposed High Speed Rail Development Act remains 125 miles per hour or higher, New York's Empire Corridor may be the only corridor in the country with a reasonable chance of meeting the criterion in the near term.

Both incremental improvements to New York's existing rail corridor and Maglev are expected to fully cover ongoing O&M costs and, in the case of Maglev, system revenues may also help recover some portion of the capital costs, particularly if regional extensions are implemented. The timing and firm commitment of Federal cost-share dollars to these initiatives is key to any financial analysis. The financial analysis presented in Section 7 of this report discusses opportunities for Federal funding as well as system revenues and costs.

DO-NOTHING SCENARIO

Without the benefit of HSGT, the projected growth in travel, either by air, auto or rail must be absorbed by existing systems. Congestion will continue to increase at urban airports. Assuming the current mix of aircraft size and capacity, from 17,000 to 34,000 excess capacity aircraft flights will be added annually to the flight schedules. Delays will further exacerbate the loss of traveler productivity.

As air traffic demand increases, efficiency gains from deregulation and privatization will be offset by fare increases resulting from environmental impact fees, land fees, removal of duty-free subsidies to airports, increasingly scarce landing slots and costs of increased security.⁷

Demand for auto travel continues to increase with development of distant suburbs and edge cities that compete for the new transportation links to the core cities and intercity routes.

HSGT is being considered against a backdrop of growing demands on existing modes and efforts by major cities to conform to clean-air standards. Automobile and truck traffic dominates the regional and interurban commuting market, due to the low costs for short distances compared to competing modes.

Some of the implications of not implementing a HSGT system in New York State include:

- Benefits of reducing pollution emissions will not be realized making conformity to the mandated clean-air standards more difficult;

⁷ Allport, R. and M. Brown, "The Economic Benefits of the European High Speed Rail Network", Presented at the 72nd Annual Meeting of the Transportation Research Board, January 1993, Washington, D.C. (Paper No. 930282)

- A variety of air pollutant emissions will increase if a HSGT system is not constructed to divert air and auto passengers away from existing modes. By 2010, the increase in air pollutant emissions will be approximately 80,000 tons annually, 99 percent of which is carbon dioxide;
- Some 17.4 million gallons of distillate fuel per year will be consumed to fuel vehicular traffic and aircraft, 12.6 million gallons for air trips and 4.6 million for additional automobile trips, with the remainder for rail traffic;
- Approximately 200 additional auto accidents per year and 27 additional deaths (5.4 percent increase). To put this into context, the number of fatalities resulting from car, truck and motorcycles in 1991 in New York State was 1,120, and 41,000 nationally; and
- Airport expansion for runways and gate slots; these costs may tax the Federal allotment.

HSGT Costs and Benefits Summary

Implementing a HSGT system can produce significant indirect and tangible public benefits including improved air quality, fuel diversification, reduction in transportation-related accidents, increased household earnings, temporary and permanent jobs, and improved productivity through reduced travel times and increased mobility. Unfortunately, these benefits are not easily factored into the financing equation.

The costs and benefits of a HSGT system in New York State are summarized in Table S-11.

Table S-11. HSGT Comparative Summary.

Cost or Benefit	Incremental Rail Improvement	VHSR	Maglev
Capital Costs	\$1-2 billion ¹	\$7 billion	\$17 billion
O&M Costs	N/A	\$97 million	\$100.5 million
Farebox Revenues	\$297 million	\$343 million	\$497 million
Freight Revenues ²	Not included	\$231 million	\$231 million
Pollution Cost Savings	Not included	\$8.2 million	\$4.2 million
#Jobs Construction O&M	Not included	90,000 30,000	190,000 37,000
Increased State Output Construction O&M	Not included	\$11.8 million \$3.5 billion	\$25 billion \$4.3 billion
Enhanced household earnings Construction O&M	Not included	\$3.6 billion \$1.2 billion	\$7.8 billion \$1.5 billion

¹ New York State Department of Transportation, New York State and Local Railroad Advisory Council Report

² New York State intra-state freight only, assuming a regional transportation network is in place with all supporting infrastructure

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Section 1

COMPARISON OF HIGH SPEED GROUND TRANSPORTATION TECHNOLOGIES

Summary

This section summarized the various HSGT technologies that are commercially available or proposed for commercial revenue service. A representative from each category: either incremental rail, VHSR or Maglev, has been carried forward in the remaining analyses. The system characteristics and specifications used in other analyses are best known and represent the most advanced and proven designs in each category.

The incremental option is modeled after a tilt train with an active tilt mechanism in the coaches and powered by a non-electric turbine locomotive in a push-pull arrangement on existing tracks with appropriate safety modifications and upgrades assumed.

The VHSR option referenced through the remainder of the analyses is based on TGV equipment using a 1-5-1 trainset configuration. This system operates on a separate dual track laying within the existing rail ROW to the greatest extent possible.

The Maglev configuration assumed in later analyses is a Transrapid TR07 5-car configuration operating on an elevated spine girder guideway (reference SCD guideway designed by Parsons Brinckerhoff). Two simulations were run: one assuming tilt capability and one assuming standard no tilt capability.

The following discusses present definitions and descriptions for three categories of rail or Maglev technologies:

- Incremental rail proposed as steel wheel on rail operating on existing track, powered by diesel-electric or gas-electric turbine, capable of maximum speeds of 150 mph (225 kph);
- Very High Speed Rail (VHSR) defined as an electrically powered steel wheel operating at a maximum speed of 200 mph (300 kph) on a grade separated dual track dedicated to high speed passenger service; and
- Maglev that operates on a dedicated guideway and is powered by a linear synchronous motor to attain speeds of 300 mph.

Evaluation of Steel Wheel HSR Technologies

Advanced systems, in daily revenue operation today in Europe and Japan, have achieved billions of passenger-miles of service over the past three decades. During test operations the French TGV has achieved world speed records (515 kph or 322 mph) for guided ground transportation under special test conditions and equipment configurations.

Different available and proposed candidate technologies in these categories may differ in delivered performance by virtue of changes in the propulsion power-to-weight ratio. Electrification of the system provides a more significant positive effect on this ratio than a reduction in weight because of inherent design advantages. In the context of the New York study, however, it is assumed that the conventional and tilt train systems would not be electrified for several reasons including:

- Electrification has a high initial cost in relation to the performance improvements that can be achieved over and above a non-electrified train system (if that system has good power-to-weight ratio within the maximum speed range of these systems).
- To include electrification in the conventional and tilt systems in the Empire corridor context would suggest that meaningful improvements could not be achieved without electrification, which is not so.

Trains operating around curves of a given radius are limited in speed by Federal safety regulations and the amount of superelevation (or cant) present. The FRA requirement limits the speed to that which is equivalent of three inches of unbalanced elevation¹. This limitation means that if the track were superelevated an additional three inches assuming the same speed, the passenger would feel no lateral force (balanced elevation). Notwithstanding this regulation, FRA has granted a limited waiver of this requirement to Amtrak and allows Amtrak to operate at four inches or five inches of unbalanced elevation at specified curves with specified equipment in the Northeast Corridor.

As regulation in high speed ground transportation is still evolving, for performance evaluation purposes this study assumes that operation with conventional equipment at five inches of unbalance may be achieved through appropriate construction and maintenance practices, and FRA authorization. This limit already exists on the Empire Corridor. It should be noted that at present the owning carrier must request such relief from FRA, and there can be no assurance that a given carrier will make such a request or that it will be granted. Liability issues must be resolved for HSGT transportation in any shared ROW.

¹Speed on curves is limited according to the formula $V_m = ((E_a + E_u) \times R / 4.01))^{1/2}$ or $((E_a + E_u) / 0.0007D))^{1/2}$, where V_m = maximum speed (mph), E_a = actual superelevation in inches; E_u = unbalanced elevation in inches, and R = curve radius in feet (or D = degree of curve). Federal track safety standards limit E_u to 3 inches and E_a to 6 inches.

The following discussion presents background on the existing conventional equipment and its performance capabilities against which VHSR and Maglev systems can be compared.

Conventional HSR

Existing Amtrak service is capable of operating at speeds of 125 mph (185 kph) on certain sections of the Northeast Corridor (NEC) under a waiver granted by the FRA. The importance of the NEC to Amtrak business and the mobility of the region has spurred Amtrak to test different equipment to achieve higher speeds. The existing rail lines in the Empire Corridor often follow the "water level route" that provides low grades but can be tortuous, and thus not complementary to large increases in speed. Along many segments development has encroached on existing rail ROW offering little room for expansion for a parallel facility without displacing businesses and residences. Such a ROW would not be suitable for VHSR application.

The combination of track superelevation and unbalanced elevation determine the minimum radius of curvature at which a specific maximum speed may be achieved. Table 1.1 shows the minimum radius of track curvature required for 110 mph (176 kph) through 125 mph (188 kph) at four, five, and six inches of track superelevation, for three levels of unbalance -- 3 inches, 4 inches, and 5 inches.

Table 1-1. Conventional HSR: Minimum Curve Radius.

	Actual Track Superelevation		
	4"	5"	6"
At 3-in. Unbalance (ft.)			
110 mph	6933	6067	5392
115 mph	7578	6631	5894
120 mph	8251	7220	6417
125 mph	8953	7834	6963
At 4-in. Unbalance (ft.)			
110 mph	6067	5392	4853
115 mph	6631	5894	5304
120 mph	7220	6417	5776
125 mph	7834	6936	6267
At 5-in. Unbalance (ft.)			
110 mph	5392	4853	4412
115 mph	5894	5304	4822
120 mph	6417	5776	5251
125 mph	6936	6267	5697

As reference points, curvature measured in degrees corresponds to curve radii in feet, for example: 2 deg. = 2865 ft radius; 1 deg = 5730 ft radius, 50' = 6876 ft radius, 40' = 8595 ft.

There is potential for improving speed performance on curves through curve realignment, which may take place either within the existing ROW (minor realignment) or outside the existing ROW (major realignment). Major realignments may not require large deviations from the existing rail line, however, and the amount of land required is often not large. In open country where development has not built up to the railroad property line, this approach may be of considerable interest. Unfortunately, most of the lower-speed areas are in more developed environments, where curve realignment projects are still possible but at higher capital cost.

Conventional Vehicle Candidates

The choice of passenger coach and locomotive equipment for Conventional HSR service is fairly straightforward, although these will differ somewhat from today's Amtrak service. The principal

requirement that is non-standard is the 110 mph minimum top speed. Present Amtrak diesels (General Motors F40PHs) are rated at 90 mph.

General Electric Locomotives

Amtrak currently has on order a fleet of 32 diesel-electric locomotives, built by General Electric, that have an improved cab design, stylish "ICE-look" exterior design, and a top speed in excess of 100 mph (160 kph). Ten of these locomotives, designated AMD-103DP, will have third rail capability. Slated for delivery between May and December 1993, these locomotives could pair with existing Amfleet or Horizon cars for a base-level incremental HSR service in various Amtrak corridors with 79 mph service today. In the Empire corridor, however, top speeds of 110 mph are already being achieved, and 125 mph speeds are being sought, beyond the capability of the AMD-103DP.

Advanced RTL Turboliner

A prime candidate for self-powered conventional HSR service is the advanced RTL Turboliner locomotive powered trainset. The existing RTG/RTL Turboliners have had extensive service experience in the New York City - Albany - Buffalo corridor. This fleet is not Amtrak's standard and some maintenance difficulties have been encountered. The manufacturers have proposed a next-generation RTL power car that would use higher powered turbines with an excellent reliability record. Such power cars would have superior performance to the present RTL power units and could achieve 125 mph (188 kph) maximum speeds.

Although the advanced RTL power car has never been produced, all of its major components exist today. With interior modifications, the existing RTL coach design would represent a proven design with demonstrated popularity as a mate to the RTL power car, and permit better performance owing to its lightweight design. New RTL power cars could be designed to match with Amfleet or other conventional equipment as an alternate.

British Rail HST Locomotive

An additional candidate that could be considered for this service is the British Rail HST locomotive, with a maximum speed capability of 125 mph, hauling its associated Mark III coaches or Amfleet III/Horizon cars. The HST locomotive has a power-to-weight ratio somewhat improved over the Amtrak AMD103DP. It is a less radical improvement, however, compared to the RTL, and it is less compatible with the remainder of Amtrak's fleet and it represents foreign sourcing.

Conventional Power Supply/Propulsion/Performance

Diesel. The conventional HSR vehicles are prime-mover powered, that is, they carry and burn fossil fuels on board to produce their propulsive power. The standard Amtrak locomotives, and their newest order as well, burn diesel oil and generate electricity to power traction motors.

Gas Turbine. The advanced RTL power cars carry and burn kerosene in gas turbines and drive the axles through a mechanical, as opposed to electrical, transmission. The advanced RTL locomotive achieves a higher overall power-to-weight ratio than the conventional diesel-hauled consists as a result of:

- The higher specific power rating of gas turbines (power per pound of prime mover weight) compared with diesel engines; and
- A concentration on lightweight construction.

Conventional Power-to-Weight Ratio

This higher power-to-weight ratio translates into improved accelerating performance. The table below shows power, weight, and seating information for typical Empire corridor equipment.

Table 1-2. Conventional HSR: Power, Weight and Seating on Typical Empire Corridor Consists.

Consist / Max. speed	Tractive HP	Loco Weight (tons)	Car Weight (tons)	Total Weight (tons)	Max Axle Load (T)	HP/Ton	No. of Seats
F70/6 Horizon 100 mph	2650	132	254	386	33.0	6.9	471
AMD103DP/6 Horizon 103 mph	3550	136	254	390	34.0	9.1	471
Advanced RTL/6 RTL 125 mph	2915	81.5	309	390.5	20.4	7.5	432
Advanced RTL/6 Horizon (125 mph)	2915	81.5	254	335.5	20.4	8.7	471

Tilt Trains

Tilt trains are considered one of the answers to incremental improvements on existing passenger rail lines.

Body tilting technology has been developed to enhance the speeds of trains on existing tracks by effectively reducing the lateral acceleration imposed on the passengers as the train progresses around a curve, permitting curves speeds to be increased. The Italian Pendolino and the Spanish TALGO trains are examples of passive tilt technology. The Italian ETR 450 (Figure 1-1) and the Swedish X-2000 (Figure 1-2) and the Canadian LRC are examples of active tilt trains using accelerometers in the locomotive to activate the tilt mechanism.

Over the years both passive and active tilt mechanisms have been tried with varying success. One likely candidate for tilt HSR service in the U.S. today is the ABB Traction X-2000 train as it has substantial service experience in Sweden and limited revenue operations in the U.S. Northeast Corridor.

Figure 1-1. Italian Pendolino Tilt Train.

Figure 1-2. Swedish X-2000 Tilt Train.

Curvature and Speed Limitations

As with the conventional HSR case, the combination of track superelevation and unbalanced elevation determine the minimum radius of curvature at which maximum speed may be achieved. Of course their increased unbalanced elevations have a significant effect on the curving speed of tilt HSR trains. The table below shows the minimum radius of curvature at 110 mph through 150 mph at four, five, and six inches of track superelevation, for three levels of unbalance--6 inches, 8 inches, and 10 inches. As a point of reference, FRA authorized Amtrak to operate the X-2000 at 9 inches of unbalance in its NEC demonstration service, and the test program included operations at up to 12.5 inches of unbalance.

Table 1-3. Tilt HSR: Minimum Curve Radius. *

	Actual Track Superelevation		
	4"	5"	6"
At 6-in. Unbalance			
110 mph	4853'	4412'	4044'
125 mph	6267'	5697'	5223'
150 mph	9023'	8202'	7518'
At 8-in. Unbalance			
110 mph	4044'	3733'	3467'
125 mph	5223'	4821'	4476'
150 mph	7518'	6940'	6445'
At 10-in. Unbalance			
110 mph	3467'	3235'	3033'
125 mph	4476'	4178'	3917'
150 mph	6445'	6015'	5639'

* See Note, Table 1-1 on curve radii requirements..

The Swedish X-2000

The ASEA-Brown Boveri (ABB) X-2000 tilting train is an outgrowth of an extensive test program with train X-15 and earlier test vehicles carried out in cooperation with Swedish State Railways (SJ) during the late 1970s and early 1980s. SJ has a firm order for 20 trains (each consisting of one power car, four coaches, and a cab coach) and an option for an additional 32 sets. Deliveries began in September 1990 and

will continue through 1994 for the first 20. The train began service on the 270-mile Stockholm-Goteborg line where, with a top speed of 125 mph, it is projected to reduce the running time 50 minutes -- from 3 hours 49 minutes to 2 hours 59 minutes -- a 22 percent overall reduction.

The X-2000, like most tilting trainsets, is based on electric propulsion, which raises the question of what the motive power source would be in U.S. low-capital-investment corridor applications. The train, of stainless steel construction, has the following characteristics:

- A traditional arrangement of two trucks per car (non-articulated) so that train length can be readily changed
- Electric locomotive and coaches that feature radial steering trucks with soft primary axle box suspensions to reduce track forces
- Coaches and a rear cab coach with active body tilting mechanisms that can tilt up to 6.5 degrees with respect to the plane of the track which is said to permit an increase of about 30 percent in speed around curves (in terms of passengers' perception of lateral force)
- A non-tilting locomotive that contains sensors to detect the presence of lateral accelerations in curves. The resulting signal is processed and used to drive hydraulic actuators to tilt the body bolster on which the car body is suspended by airsprings.
- A maximum axle load of 16.5 tons
- A continuous power rating of 3260 kW

The X-2000 has good prospects for service in the U.S. because of its proven service experience on SJ, radial steering axle boxes, the large order under production, the test and revenue demonstration program with Amtrak, and aggressive marketing and support from a very strong international company. The Florida High Speed Rail project proposed using a FastTrain derived from X-2000 technology, although this project

is now suspended. X-2000 equipment for U.S. applications would require a redesigned body structure to meet American buff load requirements, rather than European (UIC) codes.

The Italian Fiat ETR-450

The Fiat ETR-450 is an electric, multiple unit, non-articulated trainset. A total of 130 vehicles were delivered to Italian State Railways (FS). They entered service between Rome and Milan in 1988 and now also are used between Rome and Naples. The train has:

- A maximum axle load of 13.75 tons, with a per-car power rating of 312 kW
- A tilt mechanism that is activated in a similar fashion to that described for the X-2000
- Tilt capability up to 10 degrees, but limited by FS to 8 degrees to limit adverse reaction from passengers seated in window seats on the inside of a curve

The ETR-450 is an EMU. Therefore, it would not be a likely candidate for Empire corridor service unless it was proposed to electrify in the Tilt HSR case.

The Spanish TALGO

The Spanish TALGO (*Tren Articulado Ligero Goicoechea Oriol*) is a wide-gauge family of trains of which the TALGO Pendular is the most recent member. Introduced in 1980, the Pendular features:

- A passive tilting suspension system tested at up to 140 mph
- Articulated train coaches with independently rotating wheels, extremely low weight, and very low centers of inertia
- A power system consisting of conventional diesel-electric locomotives of Krauss-Maffei or, more recently, Alsthom design

TALGO trains, to be a candidate for Empire corridor service would require substantial modifications for standard gauge service and U.S. structural strength requirements.

The Canadian LRC

The LRC (Light, Rapid, Comfortable) train, produced by a Canadian consortium led by Bombardier, is a diesel-powered tilt-coach train that has been operated by Canadian National and Via Rail Canada through this writing. It has had test service experience on U.S. properties during the last fifteen years, including a test program on Amtrak's Northeast Corridor.

The locomotive has never been an outstanding performer in terms of power-to-weight ratio, and difficulties with the tilting mechanism have caused Via Rail to operate the LRC regularly with the tilt mechanism locked out. The train is no longer in production, although an updated version with improved power-to-weight ratio could be offered. The LRC was designed to meet U.S. structural strength requirements originally and would not require modifications.

It should be emphasized that the differences between various tilt-body candidates are not significant in terms of the effect of tilt technology on running times.

Power Supply/Propulsion/Performance

The same prime-mover-powered issues discussed with regard to conventional HSR trains apply to tilt HSR trains. Table 1-4 below shows power, weight, and seating information for typical Empire corridor tilt HSR consists.

Table 1-4. Tilt HSR: Power, Weight, and Seating on Typical Empire Corridor Consists.

Consist HP/Ton	Tractive HP	Loco. Wt.	Cars Wt.	Total Wt.	HP/Ton	Seats
Advanced RTL/6 X-2000 (1-5-DT)	2915	81.5	375.6	457.1	6.4	383*
2 Advanced RTL/6 X-2000 (1-6-1)	5830	163	375.6	539	10.8	411**
<i>*Assumes 4 coaches + 1 coach/buffet + driving trailer</i>						
<i>**Assumes 5 coaches + 1 coach/buffet</i>						

VHSR Technology

Capable of traveling at speeds in excess of 150 mph, the VHSR systems typically are operated on a fully dedicated ROW that facilitates speed, reduces maintenance and provides safe operation without conflict from other users. The fully dedicated ROW approach has been employed in all countries implementing HSR with the exception of Germany where freight trains share trackage, but mostly operate during the night.

As noted earlier, power-to-weight ratio has a fundamental effect on train performance as does maximum speed. Increased power-to-weight ratio permits increased acceleration rates. Such increases, especially if available at high speeds, are particularly useful in regaining speed after a speed restriction. These factors interact with the geometrically determined speed limits along the alignment in determining the overall elapsed time for a given run, including station stops.

As regulation in this area is still evolving, this study will assume for performance evaluation purposes that operation with VHSR equipment at five inches of unbalance may be achieved through appropriate construction and maintenance practices and FRA authorization. While the owning carrier must request

such relief from FRA, this can be assumed in the VHSR case since the owning carrier is the HSR sponsoring entity or a closely related entity.

The combination of track superelevation and unbalanced elevation determines the minimum radius of curvature at which maximum speed may be achieved. Table 1-5 shows the minimum radius of curvature at 150 mph through 200 mph at four, five, and six inches of track superelevation, for three levels of unbalance -- 3 inches, 4 inches, and 5 inches.

VHSR Vehicle Candidates

The leading candidate vehicles to provide VHSR service in the Empire Corridor today are the French TGV, the German ICE, and the Japanese Shinkansen (see Figures 1-3 through 1-5). These trains are described below and their respective systems characteristics are provided for comparison in Table 1-6.

The French TGV

The French National Railways (SNCF) has been developing higher-speed passenger trains and introducing them on upgraded lines in a continuous process dating back to the 1950s. The TGV experience in France provides the only current benchmark for daily commercial revenue service at speeds of 186 mph.

SNCF traditionally has held the world's speed records for wheel-on-rail systems during this period, and does so today. The present record of 322 mph exceeds the maximum speed achieved by a Maglev vehicle to date, although this is due to the presently limited length of available test tracks for Maglev trials.

TGV-PSE. Beginning with a test program in the 1970s, SNCF began development of a new super-train, *Train a Grande Vitesse* (TGV), which first entered revenue service on the Paris-Lyon route in September

Table 1-5. VHSR: Minimum Curve Radius.

Speeds	Actual Track Superelevation		
	4"	5"	6"
At 3-in. Unbalance			
150 mph	12,892'	11,281	10,127
160 mph	14,669'	12,835	11,406
170 mph	16,559'	14,489	12,880
180 mph	18,565'	16,244	14,439
190 mph	20,685'	18,099	16,088
200 mph	22,920'	20,055	17,826
At 4-in. Unbalance			
150 mph (240 kph)	11,281'	10,127'	9,025'
160 mph (256 kph)	12,835'	11,406'	10,268'
170 mph (272 kph)	14,489'	12,880'	11,592'
180 mph (288 kph)	16,244'	14,439'	12,995'
190 mph (304 kph)	18,099'	16,088'	14,479'
200 mph (320 kph)	20,055'	17,826'	16,044'
At 5-in. Unbalance			
150 mph (256 kph)	10,027'	9,025'	8,024'
160 mph	11,406'	10,268'	9,335'
170 mph (272 kph)	12,880'	11,592'	10,538'
180 mph (288 kph)	14,439'	12,995'	11,814
190 mph (304 kph)	16,088'	14,479'	13,163'
200 mph (320 kph)	17,826'	16,044'	14,585'

As reference points, curvature measured in degrees corresponds to curve radii in feet as follows: 50 min. = 6876 ft; 40 min. = 8595 ft.; 30 min = 11460 ft radius; 20 min.= 17,190 ft radius; 15 min. = 22,920 ft radius.

of 1981. The maximum speed of the train -- 168 mph (270 kph) -- was achieved on the new portions of this Paris-Southeast (PSE) line. Like its younger cousins, the TGV-PSE is articulated (trucks shared between cars at their couplings), and it has body-mounted traction motors and a low axle load (17.9 tons maximum). The TGV-PSE employs a 1-8-1 configuration carrying 368 mixed-class passengers.

TGV-A. The next generation of TGV, the TGV-Advanced RTL Atlantique (TGV-A) (Figure 1-3), entered service in 1990 between Paris and Le Mans. The TGV-A operates 1-10-1 consists carrying 485 mixed-class seats. The present maximum speed operated on the TGV-A lines is 186 mph (298 kph), although a future increase to 206 mph (330 kph) is under consideration by SNCF.

The most advanced TGV equipment is now under production for several projects:

- The Channel Tunnel equipment
- The *Alta Velocidad Española* (AVE) equipment for Spain's new Madrid-Seville high speed line
- Potential TGV-Nord equipment for Paris-Brussels-Koln-Amsterdam-Frankfurt service

These trainsets will be adapted to be compatible with the physical constraints of the different properties; the various overhead AC electric supply voltages and frequencies in use in the different countries; and, in the case of the Channel Tunnel trainsets, 750 volt DC third rail supply.

All of the TGV's since PSE have had AC propulsion, eliminating the requirement for commutator maintenance. The most recent development has been AC induction motor drive. All have steel structures meeting UIC specifications.

The German ICE

ICE-A. The German Railways (DB) development program leading to the InterCity Express (ICE) began in 1979 with preliminary trials of the prototype InterCity Experimental beginning in mid-1986. The original production equipment was a locomotive hauled, non-articulated, 1-13-1, 156 mph (250 kph), 681-seat train, with a maximum axle load of 22 tons.

The DB/ICE approach develops new lines for joint passenger and freight service, but with maximum freight axle loads of 24.75 tons. The combined passenger-freight requirements induce the DB to favor slab track for their new line designs.

ICE-M. The newer generation of equipment, ICE-M (Figure 1-4), is the international version intended for operation on the European high speed network of railway lines now being planned and constructed. This

version essentially adopts the French standard of 18.7 tons maximum axle load and 186 mph (298 kph) maximum speed. The ICE-M locomotive has lower power than the ICE-A to reduce the weight (3600 kW vs. 4800 kW) and the train length is reduced to a 1-6-1 consist carrying 370 seats. The short train length necessitates a high-voltage trainline on the car roof, because the inter-pantograph distance is too low for good current collection at high speeds. The ICEs have sophisticated AC induction motor drives with digital adhesion control, and have lower unsprung mass than the TGVs. The ICE-M also exists in the multi-current versions required to operate on the different European railway systems' power supplies.

The ICE-A entered revenue service in 1991 at 156 mph (250 kph). Additional deliveries of ICE-A equipment and first deliveries of ICE-M equipment are in production. Both trains have steel-structure locomotives and aluminum alloy-structure passenger coaches meeting UIC specifications.

The Japanese Shinkansen

Japan Railways (JR) and its predecessor Japanese National Railways operates the largest volume high speed passenger rail service in the world, if not the fastest. The first new high speed, standard gauge line (Shinkansen) (Figure 1-5) was the New Tokaido Line, between Tokyo and Osaka. It opened for revenue service in 1964 with maximum speeds of 131 mph (210 kph).

The Tokaido line, the crown jewel of the Japanese Shinkansen network, carries on the order of 160-million passengers (30-billion passenger-miles annually) and earns a substantial profit. Over the Tokaido-Sanyo portion of the network (Tokyo-Hakata) a total of 348 trains per day are operated to satisfy passenger demand. Current maximum speeds with second-generation equipment are 144 and 163 mph (230 and 261 kph) for Tokaido and Sanyo, respectively.

Figure 1-3. French TGV Atlantique.

Figure 1-4. German Inter-City Express (ICE).

Series 100. All of the Shinkansen lines operate electric multiple-unit (EMU), non-articulated trainsets popularly known as "bullet trains" because of the characteristic front end design that resembles an aircraft radome nose. The current equipment for Tokaido/Sanyo lines, known as Series 100, has:

- A 16-car, 1271 passenger consist with driving cabs at each end
- Cars of all-steel construction with an axle load of 16.5 tons
- 12 of the 16 cars with powered axles, each axle driven by a 230 kW DC traction motor with thyristor control; two unpowered bi-level cars; and certain consists run as 12-car trains without the four unpowered cars

Series 300. JR plans to increase speed on the Shinkansen lines where possible to 186 mph (300 km/hr) through signaling and vehicle changes. The vehicle platform for this improvement is the Series 300, which will differ in a number of respects from the prior Shinkansen equipment. Although this equipment is still under development, plans call for:

- An aluminum-alloy structure EMU with 15.4 tons axle load
- AC induction traction motors driven by PWM converters
- Trains in Japan to be composed of two coupled eight-car sections, with each section consisting of 5 powered cars, 1 trailer car, and 2 powered cab cars
- Total passenger load of 1213 passengers

Figure 1-5. Japanese Shinkansen passing Mt. Fuji.

Table 1-6. System Characteristics of VHSR Systems.

	FRENCH TGV	GERMAN ICE	JAPANESE SERIES 300
Maximum Design Speed (MPH)	200	200	163
Vehicle Banking	No (Under Design)	No	No
Superelevation	6° - 7°	6° - 7°	6° - 7°
Freight Capacity	Mail / Express	Yes	No
Propulsion	Electric Locomotive	Electric Locomotive	Multiple Electric Unit
Starting Acceleration	0.05 g	0.05 g	1.6 km/h/s
System Configuration	1 - 8 - 1	1 - 6 - 1	10M6T
Train Weight			710 (1/Train Set)
Capacity (Passengers)	376	370	1,323
Intermodal Operation	Yes	Yes	Yes
Maximum Grade	4% - 5%	4%	
Minimum Curve Radius	4000 M		
Safety Features	No At-Grade Crossings Fenced	ATC AFB	ATC (Double Frequency) CTC
	Automatic Warnings Large Animal Crossings	Indusl	Conitrac
Environmental Features	Noise Pollution Walls 95 dB Noise Level	Tunnel Emergency Features Wheel Noise Absorbers 92 dB Noise Level	Disaster Detection Pantograph Covers Inverted L-Shaped Walls Sound Absorbing Material
Technical Features	Body Mounted Traction Motors Low Axle Load (17.9 Tons Max)	AC Induction Motor Drives 3,600 Kw Locomotive Digital Adhesion Control	18.7 Tons Max Axle Load

VHSR General System Characteristics

Power Supply/Propulsion/Performance

Electric propulsion is required to achieve the extremely high speeds of VHSR systems. The high power-to-weight ratios of electric drives, their short-time overload capabilities, and their clean and quiet operation make them uniquely capable performers for VHSR. Electric trains can be of the locomotive-hauled type (TGV, ICE) or the multiple-unit type (JR Series 300). In either case, power would be delivered to the train through an overhead catenary system energized at high voltage, typically 25,000 volts (25 kV) at commercial frequency (60 Hz).

Electric propulsion eliminates the need for fueling operations and personnel, and the need to maintain a prime-mover combustion engine on each locomotive. Instead, the catenary is supplied with energy through substations spaced at intervals of 20 to 30 miles (32 to 48 km) along the ROW. Given the density of the existing commercial electric power grid within New York State, and the substantial capacity resources of New York State public and private power companies, the availability of power and the location of transmission lines near desired substation locations is reasonably assured.

Power-to-Weight Ratios

Electric HSR consists achieve overall power-to-weight ratios significantly higher than conventional consists of any type, because of the extremely high specific power rating of electric propulsion. This high rating translates into much-improved accelerating performance, particularly at high speeds where prime-mover power plants tend to saturate.

Acceleration Rates

As noted earlier, power-to-weight ratio has a fundamental effect on train performance as does maximum speed. Increased power-to-weight ratio permits increased acceleration rates. Such increases, especially if available at high speeds, are useful in regaining speed after a speed restriction. These factors interact with the geometrically-determined speed limits along the alignment in determining the overall elapsed time for a given run, including station stops.

The actual performance in the Empire corridor has been calculated as a part of the Corridor Evaluation. A rough indication of the performance of VHSR consists can be given, based on experience gained in other corridors. Depending on station stops, a VHSR train with a maximum speed of 200 mph (320 kph) might be expected to achieve an average speed of 125 to 140 mph (188 to 224 kph) on a typical 400-mile (640 km) corridor on dedicated ROW.

The next section of this report contains descriptions and evaluations of Maglev technologies. It is followed by a summary and comparison of the features, advantages and disadvantages of the various steel wheel and Maglev high speed rail systems to be considered in determining which technology is most appropriate for serving the needs of New York State.

Evaluation of Maglev Technologies

Overview

The principles of magnetic levitation have been known for centuries and have been put to use for some time in practical applications such as magnetic bearings. The modern age of Maglev development began in the early 1960s when Dr. James Powell of Brookhaven National Laboratory suggested that powerful

superconducting magnets be incorporated in the design of massive magnetically levitated systems capable of carrying hundreds of passengers.

During the late 1960s and early 1970s research in this field proliferated in the U.S. and abroad as new and improved techniques for levitation and propulsion were introduced. In 1975 the U.S. redirected its high speed ground transportation efforts and halted funded research in this area.

Research continued outside of the U.S. by private consortia and foreign transport agencies convinced of the benefits of the Maglev technology in terms of the enhanced speed and reduced maintenance. Currently, the most advanced Maglev systems are those developed into prototypes and tested by Germany and Japan, each having invested about \$1.25 billion to date.

The German effort has progressed to the point where the vehicles produced -- routinely operated on a 20 mile (31.5 km) closed loop test track-- are considered for commercial service between Orlando Airport and International Drive. This technology also is proposed for commercial operation on the Cal-Nevada project and the Pittsburgh Maglev, Inc project in Pennsylvania.

Two Maglev technologies have been evaluated by private interests in Japan: the high speed electrodynamic (EDS) superconducting suspension system and a conventional electromagnetic suspension system (EMS).

The main line Japanese effort, coordinated by Japan Railways (JR), is based on somewhat more sophisticated superconducting magnet technology. JR has built full scale test vehicles that are operated on a short test track.

Designed by Japan Airlines, the High Speed Surface Transport (HSST) system was conceived as a lower speed system to move passengers from city centers to the airports. The system was originally designed by the Germans and sold to the Japanese.

Several other noteworthy programs address particular applications and therefore should not be considered competitors for the high speed modes of transport. In particular, these are the Maglev installed at the Birmingham Airport in England, and the M-Bahn system, developed in Germany, both designed for slow speed (60 mph) operation as people movers.

U.S. Systems

The Maglev development effort in the U.S. has been reborn over the past several years, mainly through the efforts of Sen. Daniel Patrick Moynihan and others in the U.S. Congress. In 1989 Sen. Moynihan commissioned a Maglev Technology Advisory Committee (MTAC) that conducted an initial investigation into the benefits of Maglev transportation in the U.S.

More recently, the National Maglev Initiative (NMI), representing a joint effort of the Departments of Transportation and Energy, and the U.S. Army Corps of Engineers, initiated a coordinated program of investigation to determine if the U.S. industry is capable of making significant improvements to the German or Japanese systems for application in the U.S. Over the past two years twenty- seven research topics and four system designs were awarded to investigate new subsystem and whole system concepts. Results of the System Concept Definitions are described in this section.

In addition, a number of states, feeling the results of the growing transportation congestion and the demands for compliance with recent clean air regulation are taking an active role through their own agencies and through the sponsorship of HSGT implementation studies.

As a result of this recent U.S. activity, several interesting new U.S. Maglev concepts have emerged that are worthy of comparison to the foreign designs noted above. Four new system concepts are now under study under the auspices of the NMI's Maglev System Concept Definition (SCD) program. The four concepts

designed by teams led by Bechtel, Foster-Miller Corporation, Grumman Aerospace Corporation, and Magnaplane, Inc. are included in this comparison.

Candidate Maglev Systems

The eight Maglev design concepts investigated include:

- The German Transrapid
- Three Japanese concepts -- MLU002, MLU00X, and HSST
- Four U.S. concepts -- Grumman SCD, Bechtel SCD, Foster Miller SCD, and Magnaplane SCD

These Maglev systems are described in greater detail and evaluated below.

German Transrapid Maglev. The Transrapid Maglev system (shown in Figure 1-6) is the most highly developed Maglev in the world today and the Transrapid 07 vehicle currently is considered for commercial service in the Florida, Pittsburgh, and Cal-Nevada Projects. Transrapid International, a consortium composed of Messerschmidt-Boelkow-Blohm (MBB), Krauss Maffei, and Thyssen Henschel was begun in 1966 by The German Minister of Transport to develop progressively more advanced Maglev test vehicles. Over the period of this work, the German government has invested over \$1 billion and the private companies involved have invested about \$250 million. The consortium is now organized as Magnet Schnellbahn AG to complete development and market the Transrapid system.

The Transrapid 07 is regularly operated on a 21 mile (31.5 km) test track located at Emsland, Germany. Owing to the limitations of this closed loop track, full speed operation has not been achieved, but a record speed of 270 mph (405 kph) was reached in December 1989. The test track provided an opportunity to try different guideway constructions (all steel or steel and concrete) and different elevations above the ground. The test track also employs several switches.

Transrapid's Suspension System. In the early days of the German Maglev development program a number of different magnetic suspension techniques were considered, including the repulsive electrodynamic suspension (EDS) and the attractive electromagnetic suspension (EMS) systems. In 1977 they settled on an EMS suspension technique that uses normal (nonsuperconducting) magnets acting on the principle of magnetic attraction against an iron rail to provide lift, working against gravitational force.

Figure 1-6 Transrapid TR07 Vehicle and Guideway

This system requires a feedback control system that senses the gap between the magnet and the rail and rapidly adjusts the coil current to maintain a constant gap of one centimeter. This system will levitate at all speeds including at a standstill.

Lateral guidance is provided by additional electromagnets that attract opposing vertical side rails. The gap is maintained by a control system similar to that used on the levitation magnets.

Power for the support and guidance magnets as well as other housekeeping functions is provided by an induction generator that consists of coils mounted in the support magnets interacting with harmonics of the traveling wave in the synchronous motor propulsion system. When the vehicle is standing still, or in the event of a failure, power is supplied for a limited time by a battery bank. Although the vehicle weighs about one ton per passenger, the power to levitate is only about 1.3 kW per passenger.

Transrapid Propulsion System. The Transrapid is propelled electrically by a long stator synchronous motor that consists of three-phase windings in slots in the underside of the laminated iron rails. These windings interact magnetically with the vehicle suspension magnets. There are, of course, windings over the length of the guideway, but no propulsion power must be transferred to the vehicle.

A traveling magnetic wave moves down the guideway and carries the vehicle with it. The vehicle speed and acceleration are controlled by the traveling wave in the guideway, which is in turn controlled by power conditioning equipment located at intervals along the route. In order to limit power losses and to control power factor, the guideway is divided into active blocks of from a few hundred meters to a kilometer in length. Only the block which contains the vehicle is powered.

The windings in the guideway consist of single turns of heavy cable carrying about 1200 amps per phase at a maximum of 4500 volts. These winding assemblies are prefabricated in a factory and then laid in the

guideway by a semi-automatic machine. There are two windings per track, one on each side of the guideway.

At a steady state cruise, the power to drive the vehicle is determined primarily by its aerodynamic drag. As the vehicle is long and slender, there is little difference in drag coefficient between a Maglev vehicle and a high speed train. (Transrapid does claim, however that it has a 30 percent lower drag coefficient than the TGV due to a cleaner configuration in the underbody.) At 300 mph (450 mph) the 2-car Transrapid requires about 5.6 MW for propulsion. If appropriate acceleration rate control is programmed, then this power level need not be exceeded.

A particular advantage of most Maglev systems is their climbing capability, since they do not rely on wheel-rail adhesion. The Transrapid system is capable of negotiating 10 percent grades. Power failure on such grades would require some type of emergency braking system to hold the vehicle on grade.

Transrapid Power Conversion System. The linear synchronous motor requires a variable voltage, variable frequency power conversion system. For the Transrapid, this is provided by a system with a capacity of 31.5 MVA serving the 20 mile (31.5 km) Emsland test track. This capacity could handle four or five two-car trains at 300 mph (450 kph) cruise, corresponding to about one minute headways. The system was apparently sized to this capacity to provide rapid accelerations on the relatively short track.

The power conversion system consists of dual sections each containing two stages of step down transformers to convert the 110 kV utility power to the 1200 volts required by the rectifiers. Rectifiers and filters produce DC current which feeds banks of pulse width modulated inverters. These inverter banks (the world's largest installation of pulsed inverters on a single DC busbar) produce output frequencies from zero to 215 Hz and the variable voltage required by the system. Output transformers then step up the voltage to that required by the drive motors.

The Transrapid Guideway. The Transrapid guideway consists of 164-foot(50 m) beams of either concrete or steel construction. Each beam accommodates the twin steel guidance rails and motor windings for one vehicle. A dual guideway thus requires two beams. These beams may be mounted either on-grade or elevated. In an elevated arrangement the land below the guideway may be used for other purposes. A particular advantage of the Transrapid configuration is that the vehicle suspension system wraps around the guideway thus reducing the possibility of derailling.

The guideway alignment criterion is based on a maximum superelevation of 12 degrees and a maximum lateral load on the passengers of 0.1 g. There is no means of carriage bank presently designed into the vehicle. This results in a minimum horizontal turn radius of (2250 m) at 300 kph. Corresponding figures at 240 and 300 mph (400 and 500 kph) are 13080 and 20,500 feet(4000 and 6250 m) respectively. Vertical curves are designed for 0.05 g for summits and 0.1 g for valleys, which results in vertical curve radii of 126,156 and 63078 feet (38,580 and 19290 m) for crests and valleys, respectively, limiting the frequency of changes in elevation along the alignment.

The Transrapid vehicle operates with an air gap of approximately one centimeter between the suspension magnets and the guideway rails. Because of this tight coupling, the guideway must be precisely aligned in order to achieve a smooth ride. The guideway beams are aligned to within a tolerance of 1.8 inches (40 mm). For the 164 feet (50 m) long beams this is a tolerance of one part in 10,000.

Transrapid's Switch. The Transrapid vehicle configuration, which wraps around the guideway, offers important safety features, but it limits the possible switch mechanisms. Transrapid has designed and built a steel bending beam switch that moves the entire guideway from one position to the other. Several switch designs have been fabricated for the Emsland test track, varying in length from 220 to 492 ft. (67 to 150 m). The largest switch allows operation in the straight through direction at up to 270 mph (400 kph) and in the

turnout direction at up to 200 kph. In both cases the lateral acceleration is limited to 0.15 g (there is no superelevation in the turnout direction) and the jerk is limited to 0.5 g/sec.

Transrapid Control and Communication. A basic characteristic of the long stator synchronous motor is that control of the speed and acceleration is inherently provided by the ground-based equipment. For this reason, and others, control of the entire Transrapid system is centralized using a system that detects digitally encoded location marks on the guideway with a vehicle-mounted sensor. This vehicle position information is then transmitted over a redundant radio link to receiving antennae along the guideway and thence to the central control point via a fibre optic link. A slotted waveguide system of data transmission that was also developed and tested at Emsland may be used in future applications.

Commands are sent out from the central controller to the power conditioning units that serve the vehicles operating on the system. Speed control is effected by changes in the operating frequency of the inverters. To maximize system efficiency and power factor, the position of the vehicle in relation to the position of the traveling wave is determined by the vehicle location system (which is performed to an accuracy of within 12 mm). The drive motor voltage is varied to advance or retard the vehicle slightly to its best operating position on the wave.

Transrapid Braking. The primary braking function is provided by means of the linear motor propulsion system. Retarding the speed of the traveling wave will impose a reverse force on the vehicle and the motor will act as a generator. The energy that is now fed back to the power conversion system may theoretically be regenerated back to the utility grid. The Emsland system, however, dissipates the braking energy through braking resistors at the power conditioning station.

In the event of a failure in the propulsion system, a redundant braking system is provided with an eddy current brake acting against plates on the side of the guideway. In this case, the braking energy is dissipated as heat in this rail.

Transrapid's Operating Characteristics. Transrapid TR07 normally accelerates and decelerates at 0.1 g, and is designed for operation at speeds up to 330 mph (495 kph). The record speed to date is 270 mph (405 kph) in December 1989 at the Emsland test track. The 21 mile (3.15 km) test track, however, has a loop at each end, and a straightaway of only about 16.5 mile (11 km) so the maximum speed performance is naturally limited. The vehicle has no carriage bank capability and, with a 12 degrees guideway superelevation, requires a turn radius of 20,500 ft (6250 meters) at a speed of 330 mph (495 kph). This allows for a lateral acceleration of 0.1 g. The maximum grade capability is 10 degrees.

The vehicle is totally electric and emits no gaseous, liquid, or particulate matter. The utility electricity source, however, should be taken into consideration. Noise emission is totally due to aerodynamic turbulence over the vehicle body. The transrapid was tested for noise during operation, and it produces 93-95 dB(A) at 80 feet (24 m) from the vehicle at a speed of 270 mph, which is comparable to that produced by a typical HSR train at about 200 mph.

Train control is centralized and the vehicles are driven by the traveling wave created by the long stator linear motor. This feature provides a high degree of control over the system operation and should offer important safety and operational advantages compared to systems controlled by onboard operators.

The Transrapid vehicle is in a considerably more advanced state of development than other Maglev efforts around the world. For this reason, and perhaps due to the more open attitude of the German developers, much more data are available on the Transrapid than the other systems. Therefore, this description is more complete than those that follow.

Japanese MLU002 Maglev

The following information represents information generally available in the open literature.

The MLU002 (Figure 1- 7) represents the latest development in a long line of test vehicles resulting from a nationalized Maglev development effort by the Japanese government. The program, originally managed by the Japan National Railways (JNR), began in the early 1960s. They picked up on the theoretical work done by Powell and Danby at Brookhaven National Laboratory, and have developed operating versions

Figure 1-7. Japanese MLU002 on Test Track.

of the repulsive (electrodynamic) magnetic suspension technique using powerful superconducting magnets. This concept has improved over the years and has resulted in the present day MLU002 vehicle. This vehicle was recently destroyed by fire.

To date the Japanese effort has cost in excess of \$1 billion. Recently, a new 29 mile test system was approved for construction at a projected cost of \$2.3 billion. The national program is currently conducted by the Railway Technical Research Institute.

The MLU002 should not be considered to represent a commercial revenue vehicle in its present form. It is an experimental vehicle, but it does present the current state of development in superconducting electrodynamic Maglev technology. The MLU00X, discussed in the next section, is the Japanese design for a prototype revenue vehicle and should be considered as the best current representation of such a vehicle.

MLU Suspension System. Several different suspension configurations have been tested on the MLU001 and MLU002 vehicles operating on the 4.5 mile Miyazaki test track on the island of Kyushu. All, however, have used superconducting magnets in a repulsive (electrodynamic) arrangement.

The vehicle levitation magnets consist of racetrack-shaped coils operating in a liquid helium bath contained in vacuum insulated dewars. The air-core magnets produce a central magnetic field level of several Tesla. In the original configuration, these coils were arranged in a horizontal position under the vehicle and they reacted against horizontal coils in the guideway. These guideway coils are wound, short circuited, insulated units. As the magnetic field of the vehicle coils passes over the guideway coils, currents are induced which oppose the field produced by the vehicle coils. Although the same effect can be produced by a conducting sheet guideway, the current direction and magnitudes are more controlled in the wound coils. This results in lower magnetic drag.

At low speeds (up to about 113 mph) the magnetic suspension system is incapable of supporting the vehicle and wheels are used that are retracted during high speed operation. Recently, during a test, one of the tires went flat when the vehicle was a few hundred meters away from its service building. The operators attempted to tow the vehicle back to the building, and in doing so, the wheel rubbed on the structure and caught on fire. The resulting conflagration completely destroyed the vehicle. This accident has set the Japanese Maglev program back somewhat, but it should not be considered to represent any major deficiency in the Japanese design.

A disadvantage of this early suspension system is that it has high magnetic drag at low speeds. In fact, the drag in the 0-17 mph range is about three times that at full speed. This is partially offset by the lower aerodynamic drag at low speeds, but it still causes a significant power penalty in the lower speed area of operation. To combat this the Japanese adopted another Powell/Danby invention, the null-flux coil arrangement. These figure-eight shaped coils are mounted on the sidewalls of the guideway and interact with the usual racetrack coils in the vehicle which are now mounted on the vehicle sides. The resultant drag characteristics of this system are still highest at low speeds, but are significantly lowered over the entire speed range. The MLU002 is not equipped with an independent carriage bank mechanism.

MLU Propulsion System. The Japanese vehicles use a long stator linear synchronous motor for propulsion. The propulsion coils on the most recent configuration are mounted beneath the guideway levitation coils and act against the magnetic fields of the vehicle suspension magnets. The particular configuration of the vehicle suspension coils has resulted in a pole pitch of about two meters and consequently a maximum operating frequency of about 28 Hz. Because of this low frequency requirement, they have been able to power the system with a cycloconverter.

MLU Guideway. The guideway, of concrete construction, is "U" shaped in cross section. The propulsion and suspension coils are mounted to the inside of the outer walls. Provisions are made for the suspension wheels to roll along the base of the guideway and for lateral guide wheels to center the vehicle against the side walls.

The MLU002 suspension system operates at a clearance of 4 inches and, as a result, is very tolerant of guideway irregularities. It is postulated that one of the primary reasons the Japanese selected the EDS type system was that the large gap will make the system more earthquake proof. Tremors are so prevalent in Japan that their rail systems have sensors along the rail lines that signal a slowdown condition in the event of an earthquake.

MLU Switching. The Miyazaki test track incorporates a segmental switch. This unit, 262 feet long, consists of six segments which translate to the side on truck mechanisms. The 2560 foot turnout radius must be negotiated on the vehicle wheels at a maximum speed of 47 mph. The switch operating mechanism requires 30 seconds to actuate.

MLU Braking. Primary braking is by means of regenerative drive of the propulsion motor, as was described above for the Transrapid. Experiments have also been done with aerodynamic braking and metal shoes contacting the concrete guideway surface.

MLU Magnetic Fields. High magnetic field levels are a serious disadvantage for the MLU002 vehicle. Levels of up to 200 Gauss have been measured at the floor level in the passenger compartment. Test train passengers were asked to remove quartz watches and those wearing heart pacemakers were not allowed in the vehicle. In one noteworthy incident, the chairman of the Central JR system, a pacemaker wearer, insisted on riding in the vehicle and was not harmed.

MLU00X

MLU00X is our adopted designation for JR's new design for a commercial Maglev revenue vehicle. This vehicle is being designed for test on a new 29 mile track to be built in Yamanashi Prefecture near the city of Kofu, about 67 miles west of Tokyo. This is on the direct route from Tokyo to Osaka and, if the tests are successful and Maglev technology is selected for this route, the test link could be utilized in a revenue system.

Because of Japan's mountainous terrain, some estimate that up to 70 percent of future high speed lines may be in tunnels. For this reason the MLU00X is being optimized for tunnel travel. To minimize boring costs the vehicle is very slim, only 49 feet square in cross section.

MLU-00X Suspension System. Suspension and guidance will be provided by null-flux ground coils embedded in the concrete trough guideway as described for the MLU002. The vehicle superconducting coils, however, will be relocated to bogies between the cars to remove them to the extent possible from the passengers in an attempt to reduce the exposure of the passengers to magnetic fields. The relocation also likely helps to reduce the height of the vehicle at the expense of some elongation. There is no indication in the literature available that an independent carriage bank mechanism is being considered.

MLU-00X Propulsion System. Propulsion will be by long stator synchronous linear motor as was used in the Miyazaki test track. The stator propulsion coils are superposed over the levitation coils in the concrete guideway. The power supply will use a DC link solid state inverter rather than the cycloconverter which powered the Miyazaki track.

MLU-00X Switching. The segmented traversing switch that was used in the Miyazaki test track will be duplicated for the Yamanashi system. Consideration is being given to also building a vertical lift-off type switch as well that would use a ramp that would be lowered to the main line. It would incorporate no

levitation or propulsion components. The vehicle would coast up on its wheels at a speed of 67 mph. It is projected that this switch would cost more than the horizontal switch, but it would permit an overhead station and thus save important land cost in congested areas.

MLU-00X Magnetic Fields. It is projected that the magnetic field levels in the passenger cabins will be reduced to around 10 Gauss with the magnetic bogies located between the cars. The gangways above the bogies will require magnetic shielding to protect persons moving between cars. This is a significant improvement over the levels experienced in the MLU002, but it may prove to be inadequate.

Although the magnetic source is DC by nature, the vibration of the vehicle and the ripple caused by the discrete ground coils will present an AC component to the field in the vehicle. At the moment it is difficult to predict just what the magnitude of this component will be.

It should be noted, however, that the New York State Public Service Commission has adopted interim standards for the 60 Hz fields surrounding utility power lines. New line installations must be fenced off so as to limit the magnetic fields at the borders to no more than 0.2 Gauss. This is 50 times lower than the limit projected for the MLU00X.

It should be stressed though, that the 0.2 Gauss limit noted above is not based on any biological hazards investigation. Rather, it represents the average of other existing installations. The intent here is to limit any new installations to conditions no worse than those currently present until such time that hazard research indicates the desirability of a different limit.

On the other hand, the International Non-ionizing Radiation Committee of the International Radiation Protection Committee has established interim guidelines on limits of exposure to 50/60 Hz electric and magnetic fields. These suggest limiting exposure to the general public to 1 Gauss on a 24 hr basis or to 10

gauss for a few hours per day. A detailed discussion of the effects of EMF and recent research can be found in Section 4 of this report.

HSST

The HSST, a development of Japan Airlines (JAL), was originally conceived as a people-mover for transporting passengers from city centers to airports. The system was designed for lower speeds and cost. In its earliest stages of development, the concept was advanced for demonstration by the Transrapid consortium in Germany. The license was sold to Japan Airlines in favor of higher speed and more stable configurations advanced since that time. The HSST Company was spun off as a separate entity in 1985 but is presently in the process of being realigned with JAL and other Japanese companies.

The HSST actually represents three separate model designs. The HSST 100, 200, and 300 models indicate their design speed in kilometer per hour. Prototypes of the models 100 and 200 have been built and demonstrated at various transportation expositions.

HSST Suspension System. The suspension system is based on the attractive principle (EMS) using normal (non-superconducting) magnets similar to those of the Transrapid. The system operates with an 1.4 inch air gap. The magnets are powered by a 210 VDC supply which is picked up via sliding contacts on the guideway. There is no provision for an independent carriage bank mechanism.

Lateral guidance is provided by the main suspension magnets acting against the inverted U-shaped rails. A small displacement to the side will be countered by the magnets attempting to center themselves. The small air gap and the configuration of the suspension require a tolerance of 1 mm on the guideway rails. For this reason they are mechanically adjustable.

The suspension modules incorporate air springs for secondary suspension and hydraulically-actuated slide tables to provide lateral tracking of curved portions of the guideway. The minimum turning radius varies from 80 feet for the model 330 to 850 feet for the model 300.

HSST Propulsion System. The HSST vehicles are propelled by a linear induction motor (LIM) with an onboard short stator motor acting against an aluminum rail attached to the top of the steel levitation rail. The prototype HSST vehicles do not incorporate onboard power conditioning equipment, but rather pick up variable frequency power from the guideway. This dictates the use of high power sliding contacts, but at a maximum of 400 kVa for the present test vehicles. It is postulated that production vehicles would incorporate onboard power conditioning with a vehicle-guideway communication link for speed, thrust and position control.

Switching. HSST has been developing several switch concepts with Japanese subcontractors. Prior installations have been of the shuttle type and have not required switching. The proposed Las Vegas installation plans on incorporating guideway switching. During the past 18 months, HSST has successfully tested its segmental switch for durability in over 100,000 operating cycles and has undertaken a post-test disassembly and analysis. Additional development for the HSST-200 switch, which is of similar design, will be undertaken in connection with HSST's Nagoya project.

Magnetic Fields. No data are available on the magnetic fields in or around the HSST vehicles. The configuration uses iron core magnets as does the Transrapid and thus it should exhibit very low field levels.

The following text describes the Maglev system concepts or SCDs as proposed by the four teams. Drawings of four have been included as provided by each of the team for inclusion in this report. System descriptions are presented in alphabetical order of the Prime contractor. Specifications for the various concepts are summarized in Table 1-7, Maglev Matrix.

NATIONAL MAGLEV INITIATIVE CONCEPTS AS PROPOSED

The following are excerpts describing general configurations of the different Maglev concepts from reports of the four SCD contracts. Additional information and details are available from the Army Corps of Engineers report and comparative discussion of these concepts.

Grumman System Concept

The Grumman Team proposed a concept based on superconducting electromagnetic suspension (SEMS) that provides advantages over previous concepts. A cross section of the guideway and vehicle is shown in Figure 1-9. This baseline system is described below:

Grumman's Suspension System. The Grumman SCD incorporates a unique suspension concept employing iron-core superconducting magnets in an attractive (EMS) mode. This EMS suspension system uses dual rows of C shaped iron-core magnets attracted to laminated iron guideway rails. Primary excitation is provided by superconducting coils in toroidal vacuum dewars around the center leg of the C. These coils are driven by a basically constant current source and provide the basic lift capability.

- Each short leg of the C is encircled by a copper resistive trim coil that is driven by a power supply controlled by a gap sensor.
- The nominal gap of 4 cm is controlled by varying the trim coil currents.

Figure 1-8. Grumman Team Superconducting EMS Maglev Concept.

- The superconducting coil power supply will monitor a filtered signal from the trim coils and slowly vary the superconducting coil current to drive the trim coil current to zero.

In this manner the superconducting coils may be constructed with basically state-of-the-art DC coil technology, but at the same time, the power dissipation in the trim coils will be minimized.

The coil assemblies are mounted on swing arms to permit the lateral movement necessary to align to the track curvature. At the present time, dynamic analyses indicate that satisfactory ride comfort may be achieved without using a secondary suspension system.

Propulsion System. The propulsion system is very similar to that of the Transrapid with three phase windings laid in slots under the guideway suspension rails. The major differences are that the rails are larger in size and the pole pitch is greater. The bulk of the magnet dewars dictated a separation between the poles of about twice that of the Transrapid. This requires a lower operating frequency of the power supplies and a wider rail to achieve similar total pole areas.

The system is powered by DC link inverters of a configuration very much like that of the Transrapid.

Vehicles/Levitation, Guidance and Propulsion. The baseline vehicle consists of 50-passenger modules that are linked to form a 100 passenger vehicle; three or more modules can be linked to provide additional system capacity during peak demand.

The vehicle seating is arranged with 3 by 2 seating across with seat dimensions comparable to airline business class comfort. The vehicle has an active tilt mechanism that provides up to 9 degree of corrective tilt around curves.

The vehicle is levitated by the attractive forces between the superconducting magnets on the underside of the vehicle and the iron rail running along the underside of the guideway. This configuration results in a "wraparound" geometry similar in appearance to the Transrapid.

The Grumman Team Maglev concept is based on a superconducting laminated iron core magnet and guideway rail oriented in a "V" or angular geometry under the track slab. In this configuration, the attractive forces between the magnets and rail act through the vehicle's center of gravity.

The magnetic and rail configuration provides control of the vehicle relative to the rail in the vertical, lateral, pitch and yaw directions. Vertical controls are generated by sensing the gap clearance on the left and right sides of the vehicle and adjusting the currents in the control coils to maintain a relatively large 4 cm gap between the magnets and rail. Lateral control is achieved by differential measurements of the gap clearance between the left and right sides of the vehicle magnets. The corresponding magnet control coil currents are differentially driven for lateral guidance control. There are 48 magnets, 24 on each side of the a 100-passenger vehicle.

The iron rail is laminated and contains slots for the installation of a set of 3 phased alternating current (AC) LSM propulsion coils. The coils are powered with a variable frequency variable amplitude current that is synchronized to the vehicle's speed. Speed variations are achieved by increasing or decreasing the frequency of the AC current.

Guideway Design. Several guideway designs were evaluated before selecting the center spine box girder concept because of its relative advantages and cost savings (\$7.9 M/km or 64 percent of the total system). The guideway design is based on concrete segmental box girder that provides a wide center spine support the length of the system. The vehicles run on track slabs supported on "outriggers" extending from the

midpoint of each segment at a spacing of 15 feet. The rails are suspended under the track slab on brackets on either side for the full length.

The guideway design provides a stiff support for the Maglev loadings and adaptability with reduced penalty in costs particularly for variable span lengths.

Switching. The wraparound vehicle configuration, while offering positive derailment protection, prevents the use of a lift off switch. A horizontal moveable switch has been designed that splits the moving portions into two sections.

The switching is provided by a steel mechanical switch guideway segment. This switch is designed in two movable sections with one actuator motion. The one part of the switch segment is bent elastically to a curved section while the second segment is pivoted about a fixed point. This combined motion of the two switch sections (395 feet total length) provides a turnout speed of 143 mph.

Magnetic Fields. The iron cores of the magnets along with the iron rails confine most of the magnetic flux to the iron, with relatively minor leakage flux escaping. Predictions indicate that the flux level in the passenger cabin will be below 1.0 Gauss, which meets the interim requirements noted above.

Bechtel System Concept

Levitation, Guidance, and Propulsion. In this concept, flux canceling coils are mounted on the vehicle arranged in sets of eight as an octapole of four coils. Six sets of the coils are distributed along each side of the vehicle. Propulsion coils located on the outside sidewalls of the box beam interact with the onboard superconducting magnetic to produce thrust.

Levitation is provided by onboard superconducting coils interacting with an aluminum ladder -like structure mounted on each vertical face of the guideway. Null flux coils react against the levitation magnets to provide guidance. The critical gap for this concept is the 2 inches horizontal gap between the SC coils and the levitation ladder.

Lift off occurs at 5 to 10 m/s. Below that speed the vehicle rests on air bearing pads. By incorporating special lift coils in the guideway, the vehicle may lift off at zero speed .

Guideway mounted propulsion coils are conventionally constructed and configured as a six phase system. DC power is distributed along the guideway at 24 kV to frequency converters located near the guideway. The typical zone length of a frequency converter is 4000 m and a LSM block length is 6600 feet.

Guideway. As originally proposed, this system is based on the Electrodynamic Suspension (EDS) using a box beam guideway to support the vehicles. The guideway consists of a post tensioned, eight span concrete box girder supported on concrete piers at 84 foot spacing. Guideway banking of up to 15 degrees is planned. In conjunction with the vehicle tilt, this banking will allow the vehicle to negotiate a 10,000 foot radius curve at 134 m/s.

Fiber reinforced plastic post tensioning rods and stirrups on the upper portion of the box beam are used because of the high magnetic fields.

Vehicle. The vehicle consists of two alternative seating arrangements:

- The 106-passenger vehicle provides 90 coach seats with six abreast, and 16 first class seats with four abreast.
- The 120-passenger vehicle is an all coach seating.

The vehicle is constructed with an outer aluminum shell with an inner shell designed to tilt up to 15 degrees, while a smooth aerodynamic outer surface is maintained. Aerodynamic control surfaces are used to augment magnet guidance forces to stabilize the vehicle and thus improve ride comfort.

Figure 1-9. Bechtel Team EDS Maglev with Box Beam Guideway.

Foster Miller System Concept

Foster Miller has developed a Maglev system concept that advances the Japanese designs for the EDS suspension and linear propulsion system. In this concept, the multi-car consists:

- Can contain from two to eight 75-passenger vehicles
- Run at 300 mph in an open type, dual beam guideway using a null-flux sidewall coil levitation scheme
- Are propelled by a unique locally commutated linear synchronous motor (LCLSM) in the guideway

Vehicle and Suspension. The vehicles share bogies between each car body, and incorporate a full secondary suspension system with provision of up to 12 degrees of tilt for comfortable curve negotiation at high speeds. An overall view is shown in Figure 1-9. All ride quality goals defined by the National Maglev Initiative for Maglev system development are met over the entire speed range, and unexpected guideway irregularities of 1 inch can be safely negotiated, aided by the 100 mm running clearance.

The bogies contain fully redundant superconducting magnet/cryostats for safe operation at maximum speed. The primary suspension is provided by the interaction of these bogie magnets with vertical passive null-flux coils continuously mounted on the sidewalls of the guideway, outside the lower sides of the vehicle. Both levitation and guidance are provided by cross-connection of the guideway coils. Since all magnetic forces act in repulsion, forces always act to restore any attempt to deviate from the nominal position.

The vehicle car bodies use primarily composite construction for stiffness, weight saving, and crashworthiness, and contain airline type galleys and rest rooms, and passenger rooms akin to airline business class. Movement between cars also is possible.

Propulsion system. Vehicle consists are propelled by a new linear synchronous motor incorporated in the guideway. This comprises a layer of individually energized propulsion coils behind the null flux suspension coils in the guideway sidewalls. Each guideway propulsion coil is driven by an integral solid state controller powered from a DC bus and controlled by fiber optic signals from the integrated train management system, which uses a moving block control strategy for spacing.

Only those propulsion coils instantaneously adjacent to the passing vehicle bogies are energized, resulting in a high motor efficiency. Between bogies, the same coils are energized at a higher frequency, accomplishing power transfer to the passing vehicles without contact.

Guideway System. A twin-beam, prestressed concrete guideway with cross connections is assembled from modular, factory built components in order to provide a stable foundation for the sidewall levitation, guidance and propulsion systems.

- Guideway beam halves (shown in Figure 1-10) are produced in full 100 foot lengths and use closed-cell configurations that provide high flexural and torsional stiffness plus protection from all guideway power and services that are contained within.

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Centimeter

Inches

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Figure 1-10. Foster Miller EDS Maglev Concept.

- The center of the guideway is open, minimizing accumulation of snow and debris.
- Outer floor surfaces are included for slow speed operation, use by non-levitated emergency vehicles, and emergency passenger egress.
- Running clearances of 100 mm vertically and 75 mm laterally allow reasonable tolerances for guideway fabrication, erection and alignment.

The vehicle is therefore positively located within the guideway, which minimizes vehicle height and enables 40 percent of the vehicle side area to be protected from crosswinds and gusts.

Switching. High speed switching is achieved electrically without requiring any moving, load bearing components. This configuration uses the null-flux sidewall configuration in a vertical switching arrangement shown conceptually in Figure 1-11.

Switching is accomplished by electrically completing the null-flux coils only along the direction desired, with the vehicle inherently following the proper path. Paths overlap at the beginning of the switch, subsequently diverging at rates that meet ride comfort guidelines, depending on the speed desired. Lightweight movable outer floor surfaces, which would be used only in an unusual emergency, are provided beneath the vehicle path. This high speed switching technique enables all stations to be off line, greatly advanced RTL increasing system capacity. The vertical arrangement complements the use of elevated guideway, with stations and yards located below.

Magneplane Concept

Magneplane uses magnetic levitation to gain two crucial advantages:

- Individually targeted vehicles can operate safely at 20 second headways and stop at off line stations without slowing other traffic.

- Vehicles are supported resiliently at 6 inch clearance, and are free to self-bank in turns with airplane comfort.

Levitation. Superconducting levitation magnets at the bow and stern produce strong magnetic fields under the vehicle. When the magnets move, their fields induce image currents in a 2 cm thick aluminum sheet in the magway (guideway). These image currents behave exactly like mirror images moving with the vehicle magnets, and therefore repel them, producing a lifting force.

Sheet levitation (as the effect has been called) can produce a smooth ride at a height of several inches above the magway, even when the magway is rough. This magnetic spring is very soft but it becomes very stiff as the vehicle is pushed toward the magway, thus preventing contact. Oscillations are prevented by an active damping system (smart shock absorber).

Propulsion and Braking. The Magneplane vehicle is propelled by a linear synchronous motor (LSM) that resembles a "brushless DC motor" stretched along the magway. On the Magneplane, the rotor coils are aboard the vehicle, and the stator coils are in the magway. When they are powered with AC current, the magway coils produce a traveling wave of magnetic field. The speed of the wave depends on the frequency of the AC current.

This frequency, and thus the vehicle speed, is controlled by wayside power units that resemble the wayside transformers in a conventional railroad. These units:

- Communicate with the vehicles traveling in their blocks, controlling their speed. They can accelerate, maintain speed, or decelerate the vehicles. Each unit powers the LSM over a block of up to 2 km. Only one vehicle occupies a block at any given time, so there are never two vehicles riding the same traveling wave.

- Communicate with the central controller that manages all traffic in the system.

Guideway (Magway). The Magneplane magway can be built on grade or elevated. The upper surface forms a circular trough designed for passive synchronous motor winding, which is a meander coil potted in reinforced composite. It is flanked on each side by a curved aluminum levitation plate forming a trough of circular cross section (Figure 1-11). This trough is supported by an integral aluminum space frame, or, where long spans are necessary, by a separate girder of concrete or steel.

Magneplane Vehicles. Magneplane uses two sizes of vehicles: 45 passenger and 140 passenger. Plan and side views of the 45 passenger vehicle appear below. Dimension are in feet. Levitation and propulsion magnets are located in two bogies at the bow and stern, not below the passenger cabin. Magnets are "cable-in-conduit type" and are cooled by internal circulation of supercritical helium.

Coordinated curves. Magneplane vehicles can perform coordinated curves. A perfectly coordinated curve is a banked curve in which there is no side force on the passengers. Coordinated curves happen automatically in the vehicles because they are free to roll in the circular magway trough and the vehicle's own mass provides the rolling moment.

Curved magways are banked for a particular optimal speed (the design speed) at each point. At the design speed, the vehicle rolls such that its propulsion magnets are directly over the linear synchronous motor windings. Significant (10 degree) deviation from the design speed is acceptable, without a loss of propulsion power or ride quality.

Vehicle Switching. Magneplane vehicles must enter and exit the main magway trunk at high speed, without slowing the flow of traffic. A mechanical switch that requires bending a long section of the magway was

found to be too slow at the minimum headways of twenty seconds to allow for a switch malfunction and corrective action. It also was found to be too sensitive to icing and too maintenance intensive.

Therefore, Magneplane, Inc. invented a switch (called the magswitch) without moving parts that can be actuated and confirmed in a fraction of a second, and requires only switching power to operate, and is failsafe in the event of power failure.

The magway trough widens to form a side branch and the vehicle is guided between the main trunk and the branch by selectively opening or short circuiting two sets of passive coils by means of relays. These coils are the magnetic equivalent of the mechanical "frog" used in conventional railroad switches. They can be default-wired for the vehicle to either continue or exit the magway in the event of a power failure.

Table 1-8 summarizes the principal characteristics of the various Maglev systems discussed above.

Figure 1-11. Magneplane Team EDS Maglev Concept.

Table 1-7. Maglev Design Concepts.

Transrapid	450 kph (300 mph)	Attractive suspension with normal magnets, linear synchronous motor (LSM) propulsion
MLU002	450 kph 300 mph	Repulsion suspension with superconducting magnets, linear synchronous motor propulsion
MLU00X	500 kph 300 mph	Repulsive suspension with superconducting magnets/nullflux configuration, LSM
HSST	300 kph 200 mph	EMS-conventional electromagnets; 1/2 inch gap; LIM
Bechtel SCD		EDS/Repulsive suspension superconducting magnets box girder guideway; LSM propulsion
Foster Miller SCD	500 mph	EDS/Repulsive suspension superconducting magnets U-shaped guideway; Locally commutated LSM
Grumman SCD	483 kph	EMS suspension superconducting magnets, LSM propulsion
Magneplane SCD		Repulsive suspension with superconducting magnets Aluminum semicircular guideway

The final part of this section that follows includes, a list of systems selected for further evaluation, summaries of the descriptions presented in Sections 1A and 1B, and comparisons of the various systems included.

Table 1-8. Maglev System Specifications.

	TRANSRAPID	MLU002	MLU00X
Development Status	Demonstration	Experimental	In Design
Maximum Design Speed (km/hr)	500	N/A	500 to 600
Max. Demonstrated Speed (km/hr)	435	420	N/A
Trainset (No. of Cars)	2 to 10	1	6 to 14
Basic Vehicle Config. (No. of Cars)	2	1	14
Vehicle Seating Range	80 to 156	44	952
Seating Configuration	2+2 (1st), 2+3 (2nd)	2+2	2+1 (1st), 2+2 (2nd)
Nominal Seating	118	44	952
Vehicle Length (m)	54	22	314.4
Vehicle Height (m)	4.06	3.7	2.65
Vehicle Width (m)	3.7	3	2.8
Vehicle Empty Weight (kg)	90,000	N/A	N/A
Payload Weight (kg)	20,000	N/A	N/A
Vehicle Gross Weight (kg)	110,000	17,000	270,000
Lift-Off Speed (km/hr)	0	170	100
Maximum Grade (%)	10	N/A	10
Suspension Air Gap (cm)	1	11	10
Max. Acceleration (m/sec²)	1	2.7	N/A
Max. Deceleration (m/sec²)	0.8	2.1	N/A
Maximum Jerk (m/sec³)	0.5	N/A	N/A
Power Input (MW @ Speed)*	5.6 @ 450 km/hr	N/A	12.1 @ 500 km/hr (est)
Power Normalized to 500 km/hr*	7.7	N/A	12.1 (est)
Sp. Energy at 500 (wh/pass-km)*	130	N/A	25 (est)

* Power at vehicle, excludes power conversion efficiency (typ. 0.8-0.9) and utility conversion efficiency (typ.0.33)

Section 1C

COMPARISON OF HIGH SPEED GROUND TRANSPORTATION TECHNOLOGIES

Commercially Available Technologies

The purpose of this section is to provide bases for comparing the advantages and disadvantages of the alternative technologies. The discussion of this section will draw from the information and descriptions of the various high speed ground transportation technologies described in the preceding sections and from the results of the market, environmental, cost, and economic analyses presented in the following sections. For the purposes of this discussion, "high speed" systems (VHSR) are defined as those systems capable of 150 mph or greater. The VHSR equipment currently available able to attain these speeds on new dedicated alignments are the French TGV, German ICE, and Japanese Shinkansen. These three systems are competing worldwide for the high speed travel market; Taiwan and Korea are in the throes of evaluating these systems for their respective markets.

Maglev designs primarily have set goals of attaining maximum speeds in the order of 300 mph to take full advantage of the frictionless operations. Currently, there are no high speed Maglev systems in revenue service, but the German Transrapid system, having undergone extensive certification testing, is considered the mostly likely candidate for commercial implementation. A description of the operation and management of these systems has been provided at the end of this section.

Maglev Transit, Inc. has proposed to finance and build a 13.5-mile demonstration project in Orlando Florida using Transrapid technology to connect Orlando International Airport with International Drive, the location of many hotels and convention facilities. As in the Emsland Test Facility, Transrapid speeds will be limited by the length of the guideway. The Federal Railroad Administration has been cooperating with

the Florida Department of Transportation and Maglev Transit, Inc. to facilitate application for waiver for high speed operations.

Where We are Today

There is no precedent for rail operations in excess of 110 mph over grade crossings in the U.S. today. This speed is considered a limiting value for such operations, although no specific federal regulation would prevent higher speed operation at the present time. Existing Amtrak service is capable of operating at speeds of 125 mph on certain sections of the Northeast Corridor under a waiver granted by the Federal Railroad Administration. Tilt train technology is being reviewed by many states in the U.S. as a means to increase speeds on existing track without an expensive track realignment program. As part of an incremental improvement program on the Northeast Corridor, the Swedish-built X-2000 tilt train is being tested in revenue service between Washington, D.C. and New York City to improve the speeds over those achieved by the Metroliner Service.

In an effort to reduce the impact of a new dedicated corridor for an HSGT system and to mitigate land acquisition costs, both VHSR and Maglev feasibility studies have focused on sharing the ROWs of interstate highways and existing rail lines. The performance of these systems can be compromised where the alignment must follow a geographically constrained path or an existing route designed for other modes operating at slower speeds. High speed trains and Maglev are designed to operate on dedicated rights-of-way over most of the system alignment with the exception of access to urban stations where speeds are restricted and new real estate unavailable for new development. .

Trains operating at the 150 to 200 maximum speeds envisioned for this class require that the right-of-way be fitted with an Automatic Train Control (ATC) or similar systems for passenger safety and to satisfy Federal Railroad Administration (FRA) requirements. All trains operated over the high-speed portions of the line so outfitted must also be equipped with compatible ATC equipment.

Integration with Commuter and Freight Operations

Integration of HSR service with commuter rail is facilitated by the shared use of the route structure. In many cases, local fixed guideway transit (light rail or Metro/subway systems) and bus systems already radiate from commuter rail stations, facilitating integration with any HSR service applied to the corridor. Freight and passenger capacity are a function of the system configuration, particularly of the number of tracks and the type of signaling employed on the route. HSR applications on single-and-double track have been studied and shown to be feasible where freight traffic is low and passenger demand is no more than moderate. Any serious consideration of providing reliable hourly HSR service virtually requires a double-track system with bi-directional, centralized traffic control (CTC) signaling.

In the New York corridors, heavy freight train density and commuter train operation in Metro-North territory has resulted in a multiple track configuration for much of the route. The combination of heavy demand for use of the route and control of the dispatching by the freight/commuter owner/operator places constraints on the number of HSR trains that can be operated.

Such operations are negotiated between the HSR sponsoring entity and the owner/operator. It is difficult to make general conclusions as to frequency of feasible service without detailed simulations. Hourly operations of HSR trains under these conditions should be practicable and will serve as a target level for our purposes.

Right-of-Way/Alignment

Conventional HSR operations take advantage of existing railroad infrastructure and generally would not be considered for application along interstate rights-of-way. There is nothing to prevent this application other than cost, however, and indeed, many interstate highway ROWs parallel pre-existing railroad corridors.

One potentially attractive use of interstate ROWs would be partial relocation of a conventional rail line to an existing and compatible interstate ROW to reach 125 mph maximum speeds, although this appears not to be the case in New York State. Such a relocation could preclude the necessity of constructing numerous grade separations at grade crossings that might exist on the rail ROW if the highway corridor has available width with grade separations already in place. Unfortunately, this condition does not generally apply to the NYS Thruway corridor.

Curvature and Speed Limitations

The curvature of the existing rail line dictates the maximum speeds that can be achieved in an HSR program. In the joint-use scenario embedded in the conventional HSR approach, freight railroad owners may not permit track superelevation greater than four inches. While special conditions may justify an increase in this value, it is an assumed maximum in this study outside Metro-North territory. The existing Empire corridor contains up to 6 inches superelevation at a number of locations.

Acceleration

Power-to-weight ratio has a fundamental effect on train performance as does maximum speed. An increased power-to-weight ratio permits increased acceleration rates. Such increases in acceleration rates, especially if available at high speeds, are particularly useful in regaining speed after a speed restriction. These equipment characteristics interact with the geometrically determined speed limits along the alignment in determining the overall elapsed time for a given run. These run times which include station stops, are presented in Section 2.

TILT HSR Systems

The introduction of Tilt HSR trains is in most respects similar to the Conventional HSR trains described in the preceding section. This is not surprising as tilt equipment was developed to improve travel times on existing track by compensating for lateral forces on passengers in curves. Tilting is achieved through either

passive or active response in curves.² The Swedish X-2000, recently deployed on the Northeast Corridor for testing by Amtrak, is an example of the active tilt mechanism initiated by accelerometers located in the locomotive. The Spanish TALGO trains are examples of passive tilt technology. The basic infrastructure requirements are the same for tilt trains or conventional trains except for a relaxed curve radius requirement. If allowed to run on designated or improved track average speeds increase accordingly.

For the purpose of this study tilt technology includes non-electric or fossil fuel powered locomotives capable of similar speeds. Although this technology is not yet commercially available, the demand for such equipment has focused the industry efforts in the design of these higher horsepower, lower weight locomotives.

Tilt trains do have an additional failure mode. The tilt system can fail to tilt or fail in a full-tilt lockup mode. In either case, a service interruption may be required when the failure is detected, and the train must then proceed as if it were a conventional HSR train, i.e., at normal speeds on curves. The element of reliability must be considered in evaluating a tilt train design.

Right-of-Way/Alignment

The curvature of the existing rail line will dictate the commercial speeds that can be achieved in a tilt HSR program to a large degree. Amtrak and FRA have conducted joint test programs in the Northeast Corridor operating the Canadian-built LRC tilt train at unbalanced elevations up to 11 inches, for test purposes. Amtrak and FRA are conducting a test and revenue demonstration program that began in December 1992 in connection with the X-2000's trials on the Northeast Corridor. In this program instrumented wheel sets gather vertical and lateral force data during curve negotiation.

²Passive tilt trains have their roll center located above the center of gravity and tilt by natural pendulum action. Active tilt trains use mechanical actuators to rotate the carbody and do not require the elevated roll center or the outward motion of the center of gravity for operations.

The goal of the test program is to certify the X-2000 for limited revenue operation in the New York-Boston portion of the Northeast Corridor. The manufacturer is believed to be advocating a significantly higher unbalance than now operated with conventional trains, on the order of 10 inches. Regulation in this area (for speeds greater than 110 mph generally) is still evolving, and the outcome of the test program may determine if 10-inch unbalance is acceptable or not.³

The great advantage of tilt HSR trains is that they can provide improvement in curve speeds without resorting to capital intensive relocation. This approach can be of significant benefit where the existing alignment is curvy.

Lateral Clearance

An additional alignment issue for tilt trains is the subject of lateral clearance. Depending on the particular train design approach to vehicle outline, suspension design, and tilt mechanism kinematics, a car may tend to swing outward in rounding a curve and it may intrude on the clearance envelope. This tendency needs to be closely examined during design and testing programs.

Possible outgrowths of implementing a tilt HSR program include limitation of the degree of tilting, modifying side clearances, and increasing track centers at specific locations. These factors can work to limit the advantages of the tilt feature and to increase the costs of implementing the project.

³As mentioned previously, unbalances of up to 12.5 inches were experienced during the test program, and FRA approved a 9 inch unbalance for the X-2000 revenue demonstration program. This approval was on a curve-by-curve basis and included the passenger accelerations during spiral transitions into and out of curved track sections.

Very High Speed Rail Systems (VHSR)

Unlike conventional and tilt HSR systems, VHSR systems have characteristics so markedly different from conventional railways that they require dedicated tracks for their operation. This requirement provides freedom to exploit the full capabilities of the infrastructure for HSR passenger services without conflict from commuter and/or freight operators. However, it also means that the passenger operation must carry the full burden of maintaining and amortizing the infrastructure.

Safety and Control

VHSR trains operating at the 150-200 mph maximum speeds envisioned for this class require an advanced Automatic Train Control (ATC) system, not only to satisfy FRA regulations, but to ensure safety and retain tight control of rail operations.

In the HSR corridor, all highway crossings would be separated as a matter of good safety practice, even though no specific federal or state regulation requires this at the present time.

Operation in Dense Urban Areas

New HSR alignments in the most urban areas will be more difficult and costly to assemble because of the dense development around older cities, particularly in eastern corridors such as the Empire Corridor.

- In many instances it will prove advantageous to use some ROW width to construct parallel dedicated tracks for the HSR service, in which case no physical connection need be made with the existing railroad.
- In more physically constrained cases, it may be necessary to merge the HSR line into the existing rail line, in which case the operation would become a joint operation for the extent of the merged

territory. It would either be under joint control or more likely under control of the owner/operator, such as Metro-North in the New York City area.

For operating considerations in these merged zones, the discussion under conventional HSR systems is applicable. It is clearly important from a service quality point of view that there be close coordination and mutuality of interest between the HSR operator and any cooperating owners. Contract provisions appropriate to the specific application would be expected to promote such a mutuality of interest.

Intermodal Connections

To the degree that access to the central cities is gained on a shared-use route, integration of HSR service with commuter rail would likely be good to excellent. In many cases, local fixed-guideway transit (light rail or metro/subway systems) and bus systems already radiate from commuter rail stations. Therefore, they would be very well integrated with any HSR service applied to the corridor.

Where there is not direct access to the central city or not by traditional rail, integration with local and regional transit must be carefully designed to promote a true intermodal service. Provisions of the ISTEA legislation may be a source of funds to further such intermodal connections.

Passenger Capacity

Passenger capacity on a VHRS line is extremely high. VHRS trains could operate every four or five minutes in each direction in a typical double-track operation that would be required to serve the market demand of a financially successful corridor. Such a system with 12- to 16-car trains could carry:

- Between 17,000 and 38,000 passengers per hour
- 100 million to 220 million passengers per year with a 16-hour operating day

These capacities assume no bottlenecks or capacity restrictions at urban terminals. Nonetheless, it is evident that VHSR systems can provide large limiting capacities, large enough for any foreseeable market application at the present time.

Right-of-Way Alignment

VHSR systems require alignments with limited curvature to achieve their best performance , and that leads to their application on new rights-of-way in general. Many segments of the U.S. interstate highway system appear at first glance to have limited curvature, so the thought has been advanced that interstate highway rights-of-way would be ideal for HSR systems. This notion of utilizing an existing transportation corridor is extremely attractive from an environmental viewpoint. Also, having a suitable ROW made available without condemnation and at potentially zero cost would be advantageous.

Unfortunately, interstate highway rights-of-way are not the panacea some think them to be for several reasons:

- Even the straight portions of interstate highways contain significant curvature, but this is a site-specific phenomenon that must be examined in detail on a local level.
- ROW widths are not always sufficient to accommodate a parallel HSR alignment.
- Even where ROW widths can accommodate a parallel HSR system, existing highway overpasses may have insufficient widths to permit the parallel HSR route without major reconstruction. Costs would be incurred to provide either under- or overpasses of the track at existing highway overpasses.
- The best choice is likely to be an artful combination of existing interstate or other highway alignment, existing railroad alignment, and new alignment.

Curvature

As stated previously, curvature of the new VHRS rail line will dictate to a large degree the maximum speeds that can be achieved in a HSR program. In the dedicated-use scenario appropriate for the VHRS approach, the owning entity will specify track superelevation to a level appropriate to high-speed passenger train operation. This could exceed six inches (European practice approaches seven inches at times). This study assumes a full six inches of track superelevation as the standard in all new construction territory.

Safety/Environmental

Operating VHRS systems in Europe and Japan have an unsurpassed operating safety record. Such service does not exist in the United States at present, but the experience in Europe and Japan is instructive:

- Japan Railways and its predecessor Japanese National Railways have been operating Shinkansen "bullet trains" for over 25 years at speeds between 130 mph and 168 mph maximum speeds without a fatality.
- French National Railways (SNCF) has operated TGV service between 168 and 186 mph maximum speeds on an expanding network of lines since 1981. During this period there have been no passenger fatalities.

An indication of the fact that HSR trains are operating within a significant margin of safety is given by the SNCF's achievement of the latest world's speed record of 322 mph on May 18, 1990. This record was achieved not on a test track but on the new TGV-Advanced RTL antique line with a special non-revenue train.

A principal cause of train accidents is highway-railway crossings at grade. VHRS systems have none.

Further, VHRS alignments are fully fenced to prevent trespassers or animals from entering the roadway.

In addition to the traditional safety systems described under conventional HSR systems, VHRS systems may have additional protection systems providing automatic warning of earthquake, high winds, or track obstruction.

MAGLEV SYSTEMS

This discussion uses summarized data from the Maglev demonstration programs of the German and Japanese and the conceptual designs of systems proposed by participants in the National Maglev Initiative System Concept Definitions.

Maximum Speeds

The maximum speeds achievable for Maglev without penalty in energy consumption is approximately 250 to 300 mph (400 to 480 kph) depending on the design of the vehicle. Over about 250 mph (400 kph), the resistance to movement is dominated by aerodynamic forces on the vehicle. High speeds are often considered but mostly in the context of a partially evacuated system. On any alignment the speeds can be compromised by the vertical profile and horizontal alignment of the guideway as these systems are constrained by the existing comfort criteria that dictate large radii curves and long spirals entering and exiting the curves.

Early concepts for Maglev alignments were based on a dedicated alignment, elevated to cross existing roads and rail and to limit access. In the U.S. shared use of the ROW of other modes has increased the complexity and demands on the design of the system. Transrapid's vehicle does not tilt and the Emsland dedicated guideway is superelevated up to 12 degrees for their test track. National Maglev Initiative concepts have all proposed guideway superelevations exceeding this value and the addition of a tilting vehicle in an attempt to maximize the use of highway rights-of-way without jeopardizing all the performance or speed advantage for which it was conceived.

Integration with Existing Regional Transportation

Intermodal connections are required to assist local travelers connections to the intercity high speed Maglev system. Unlike rail that currently or recently served many of the cities in the region, Maglev will have to establish new stations or access into urban stations using existing rights-of-way. Entry into Penn Station is restricted for Maglev by a very tight curve in the North access tunnel that is not negotiable, even at low speeds.⁴ Realignment of this curve requires extensive study and involves considerable expense.

Right-of-Way/Alignment

The benefit of using existing ROWs is lower cost and reduced environmental impacts. Compared to the construction costs of a Maglev system across New York State, estimated to be \$17 Billion 1993 dollars, the cost of acquiring new land for ROW outside of the existing ROW are minor. The cost of planning and the costs of obtaining the environmental assessment and approvals however, can add to the costs of land located far outside the existing ROW.

The length of spiral entering and existing complex curves can result in additional excursions or more cross-overs of the existing facility, complicating the design and raising the impact during construction. The existing land topography and the constraints on the vertical curve of the Maglev alignment may result in very high structures to cross incised valleys or to clear multi-level interchanges if clearances cannot be provided between levels of flyovers. Similarly, vertical curve limits may require some speed restriction if a cut or tunnel section is designed to pass under an existing overpass or interchange. These geometrical challenges necessitate detailed evaluation of the alignment profile.

⁴Gillam M. and E. Gilcrease, 1992, Rail/Maglev Intermodal Evaluation, Federal Railroad Administration, BAA DTRS-91.

If Maglev uses the existing rail corridor for parts of the alignment or to access a New York City terminal, clearance of the adjacent rail catenary system must be provided. Further investigation is required to assess the number of cuts and tunnels along the respective rights-of-ways and their dimensions to determine if the Maglev vehicles can clear without obstruction and if there would be an impact on the speed through these sections. Maglev clearance through the tunnel access into major rail urban stations was evaluated by Gillam and Gilcrease (1992).⁵ None of the vehicle designs operating or conceived to date are able to clear the AAR rail envelope. Alternative at grade or new tunnel alternatives would be required to cross the Hudson River and require additional planning and engineering.

Comparison of VHSR and Maglev Technologies

A selection of a particular HSGT technology may be based on many factors, not the least of which are: cost schedule for implementation, ridership revenues, economic benefits, comparative environmental impacts and benefits, and regional framework. The HSGT options discussed here need not be mutually exclusive but could be considered as parts of a comprehensive plan in which one alternative may best serve one part of the State versus another. This is particularly true if short term improvements are required. The following Table provides some relative terms for comparing the three alternative speed categories : incremental rail (tilt), VHSR, and Maglev. A more detailed discussion of these factors and more quantitative values are provided in each section of this report.

⁵Ibid.

Table 1-9 summarizes the attributes of the VHSR and Maglev technologies discussed above. Although the tilt train technology was not carried through the full feasibility evaluation, similar data have been provided where possible for comparison with the VHSR and Maglev system.

Table 1-9. Comparison of Incremental, VHSR and Maglev System Characteristics.

Characteristics	Tilt Train	VHSR	Maglev
Development status	Electric in revenue service; 150 mph fossil fuel locomotive proposed	In revenue service	TR07- Demonstration US Maglev conceptual
Max. design speed	150 mph	200 mph	300 mph
Speed attained to date	150 mph	320 mph(test conditions)	270 mph (limited by track length)
Speed attainable on NYS ROW (aggressive realignment)	Max. 150 mph; average 99 mph	max. 200 mph; average 116 mph	Max. 300 mph; average 186 mph
Dedicated/shared ROW	Existing infrastructure	Dedicated new track required	Dedicated elevated guideway required
At Grade/Elevated	At. grade	At grade	Elevated (15-35 ft)
Grade crossings	Mostly grade separated	Grade separated	Grade separated
Max. Noise level	102 dB (turbo-diesel)	90 dB	95dB
Propulsion	Assumed diesel or gas-electric in study X-2000 = Electric locomotive	Electric locomotive	Electric; linear synchronous motor Conventional or superconducting
Rider Capacity	344	376 (TGV) to 1200 (Shinkansen)	100-150

Table 1-9. Comparison of Incremental, VHSR and Maglev System Characteristics (Cont'd)

Characteristics	Tilt Train	VHSR	Maglev
Minimum curve radius	approx. 6000 ft (150 mph)	13100 ft (186 mph)	7360 ft (at 186 mph) with tilt
Maximum grade	4%	4%	10%
Superelevation	6"-7"	6"-7"	12"
Tilting Capability	yes: 6 degrees	no	Existing - no NMI proposed ; 9 degrees
Radial steering trucks	yes	no	n/a
Switching	Mechanical Operational	Mechanical Operational	Mechanical Bending switch demonstrated by TR
O & M Costs	Not Available Some concern long term with new equipment that may prove maintenance intense; although design has taken needs into account	\$ 97 Million/yr \$46 Million/yr personnel; \$51M in materials, MOW and equipment	\$ 100 Million/yr \$39 Million/yr personnel; \$61 M materials, MOW, vehicle maintenance
Capital Costs	Lower: uses existing infrastructure	\$ 7 Billion	\$17 Billion
Cost per mile		\$15 million	\$36 million
Commercial availability in NYS (Estimate)	1-2 yrs assuming approval, and certification with demonstration of technology; and waivers	5-10 yrs assuming financing, franchise application; certification waiver and construction of new lines	10-15 yrs assuming financing; application approval; waiver and construction.

Section 2

**EVALUATION OF RAILROAD AND THRUWAY CORRIDORS
FOR HSGT IMPLEMENTATION**

SUMMARY

An assessment of the existing conditions provided a detailed data base used in the following exercises, including the performance simulations, noise models and land use and environmental impact discussions.

The alignments of the Empire Rail Corridor and the New York State Thruway were evaluated to determine the relative performance of a very high speed rail and Maglev technologies, respectively. The alignments were adjusted from the existing (baseline) by changing groups of curves in an effort to improve the average speed for two cases: a moderate realignment and an aggressive realignment. Using characteristics of representative equipment in each category simulated runs were made to calculate the travel times between New York City and Niagara Falls. Results of these analyses were used in subsequent ridership and economic analyses.

Alternative station locations for each major city along the route were evaluated based on a number of criteria and input from the local MPOs. These alternatives were considered in the evaluation of the alignment options for entering and exiting the cities and for providing intermodal connections to local and regional transportation.

Performance simulations using the configurations defined in Section 1 were run assuming VHSR operating on the rail corridor and Maglev along the Thruway ROW. Baseline runs assumed stops at all major cities along the corridor as the worst case. Express service between city pairs would improve travel times over those developed in the baseline case.

Constructing and operating an HSGT system was evaluated for existing railroad and New York State Thruway Authority (NYSTA) corridors. The performance of a system incorporating incremental improvements was compared to passenger service using the existing railroad corridor.

VHSR performance was assessed using existing and modified rail alignments; Maglev performance was assessed using the existing and modified NYSTA corridor. Performance simulations alignments were used as a baseline or worst-case scenario for VHSR and Maglev to compare the relative improvement in speed and travel time these modifications produce.

This section describes:

- Assessing NYSTA and Conrail/Amtrak/Metro-North railroad corridors;
- Evaluating New York City access routes;
- Realigning routes to improve performance;
- Simulated system performance;
- Locating HSGT stations; and
- Regional route extensions.

Descriptions of each corridor's evaluation are provided in the Volume 2 Appendix.

ASSESSING EXISTING CONDITIONS

The two rights-of-way (ROW) that were evaluated for an HSGT system in the New York City-Niagara Falls corridor are shown in Figure 2-1. The two ROW corridors are generally parallel, separated by the Hudson and Mohawk Rivers, and serve New York City, cities in the Hudson River valley, Albany, Utica, Syracuse, Rochester, and Buffalo. The Thruway ROW does not include the route endpoints of Niagara Falls and Manhattan, so access alternatives were developed for the Thruway alignment.

Three general sources were used to gather data:

- Material from Conrail, the New York State Department of Transportation, NYSTA, the Energy Authority, and others;
- Supplemental field investigations of milepost locations, property ownership, county border crossings, existing railroad and highway facilities, horizontal and vertical curvature, grade- and grade-separated crossings, ROW width; potential restrictions to a new VHSR/Maglev system; and current adjacent land uses; and
- USGS Quadrangle maps.

Corridor characteristics are described in Volume 4, Appendix 2-A. A sample of the data base generated and annotated for various tasks is shown in Table 2-1. Information is organized by milepost, including segment length, county, current ownership segment, existing rail traffic, number of tracks, existing maximum speed, speed restrictions, curvature, curve direction, grade, grade-crossing, grade-separations, potential environmental restrictions, typical ROW width, and land use. These data were used throughout the study to evaluate alignments, train performance calculations, relative construction costs, noise, population densities, and other relative impacts including environmental considerations.

Figure 2-1. Existing Corridors.

NEW YORK STATE THRUWAY ALIGNMENT
New York City to Niagara Falls

Milepost Locations	Length of Segment (miles)	County	Toll Barriers / Notes	Curvature (degrees)	Curve Direction	Gradient (per cent)	Existing Grade Description	Separations MP	Over/ Under	Potential Restrictions (Environmental/ Historic/Other)	Typical ROW Width (ft)	Typical Median Width (ft)	Power Line Crossings	Parking Areas	Service Areas	Adjacent Land Use
355.17 A	0.53	MONROE		0.00		1.00	PITTSFORD - MENOON	355.25 U			1000	80				RURAL
355.70 A	0.99	MONROE		0.25 S		1.00	W. BLOOMFIELD	355.70 U			1000	80				RURAL
358.88 A	0.88	MONROE		0.25 S		1.00	PITTSFORD MENOON CTR	358.88 O		Wet 357.8	1000	80			EB 358.7	RURAL
357.35 A	0.75	MONROE		0.25 S		1.00				Wet 358.0 - 358.1	400	120				RURAL
358.10 A	1.69	MONROE		0.25 S		1.00	CLOVER ST	358.25 U			700	80				RURAL
359.79 A	0.81	MONROE		0.25 S		1.00	PINNACLE	359.79 U			700	80				SUBURBAN
360.40 A	0.45	MONROE		1.07 N		1.00	RUSH - HENRIETTA	360.78 U		Church 360.84	500	120				SUBURBAN
360.85 A	0.20	MONROE		0.00		-1.00					500	120				SUBURBAN
361.05 A	0.43	MONROE		0.50 S		-1.00					500	120				SUBURBAN
361.48 A	0.64	MONROE		0.00		3.00	LVRR	361.68 O			500	120				SUBURBAN
362.12 A	0.14	MONROE		0.00		3.00	MIDDLE RD	362.12 U			500	120				SUBURBAN
362.26 A	0.18	MONROE		0.00		3.00	INTERSTATE RT 360	362.26 U			500	120				RURAL
362.44 A	0.46	MONROE	#46 HENRIETTA	0.00		-3.00	W. HENRIETTA INTER	362.44 U			500	80		362.8		RURAL
362.90 A	0.89	MONROE		0.50 S		1.00					500	120		363.3		RURAL
363.79 A	0.44	MONROE		0.00		0.00	ERIE RR	363.95 O			500	80		363.8		RURAL
364.23 A	1.27	MONROE		0.50 N		0.00	EAST RIVER RD	364.74 U			500	80				RURAL
365.50 A	0.87	MONROE		0.50 N		-1.00					500	80				INDUSTRIAL
366.17 A	0.25	MONROE		0.00		-3.00	GENESEE RIVER	366.27 O			2000	80				INDUSTRIAL
366.42 A	0.18	MONROE		0.00		-3.00	SCOTT SVILLE RD	366.42 O			2000	80				RURAL
366.80 A	0.22	MONROE		0.00		-3.00	PENNSYLVANIA RR	366.80 O		Wet 366.6 - 366.8	2000	80				RURAL
366.82 A	0.86	MONROE		0.75 S		3.00	B & O RR	367.38 O			2000	80				SUBURBAN
367.48 A	1.35	MONROE		0.00		1.00	REED ROAD	367.48 O			2000	80		367.5		SUBURBAN
368.83 A	1.02	MONROE		0.87 S		-1.00	SCOTT SVILLE CHIL	368.88 U		Wet 368.7	2000	80				SUBURBAN
369.85 A	0.07	MONROE		0.87 S		-1.00	UNION STREET	369.85 U			2000	80		369.9		RURAL
369.92 A	1.42	MONROE		0.00		-1.00	WHEATLAND CENTER	370.79 U			2000	80				RURAL
371.34 A	0.48	GENESEE		0.50 N		-1.00	CREEK TO BLUE POND	371.23 O			2000	200				RURAL
371.82 A	0.56	GENESEE		0.00		0.00				Fish Hchy 372.0	500	200				RURAL
372.38 A	0.88	GENESEE		0.00		0.00	WINSLOW RD	372.41 U			500	80				RURAL
373.26 A	0.87	GENESEE		0.00		0.00	PALMER RD	373.28 O			500	80		374.0		RURAL
374.13 A	1.47	GENESEE		0.00		0.00	RIGA - MUMFORD	374.13 U			500	80				RURAL
375.80 A	0.80	GENESEE		0.25 S		-1.00	BEULAH RD	375.03 U			700	80			WB 375.8	RURAL
376.40 A	0.44	GENESEE		0.00		0.00					450	200				RURAL
376.84 A	0.58	GENESEE		0.25 N		1.00					450	200				RURAL
377.40 A	1.18	GENESEE		0.00		1.00					450	200				RURAL
378.58 A	2.01	GENESEE	#47 LEROY	0.00		0.00	LEROY INTERCHANGE	378.58 U			2000	80				RURAL
380.57 A	2.35	GENESEE		0.00		0.00	WEST BERGEN RD	380.57 U			2000	80		380.6		RURAL
382.92 A	0.08	GENESEE		0.50 N		0.00					400	100				RURAL
383.00 A	0.10	GENESEE		0.00		-1.00					400	100				RURAL
383.10 A	0.40	GENESEE		0.50 N		-1.00					400	100				RURAL
383.50 A	1.11	GENESEE		0.00		-1.00	STAFFORD - BYRON	383.78 U			400	100				RURAL
384.81 A	0.87	GENESEE		0.00		-1.00	BLACK CREEK	384.81 O			400	100				RURAL
385.28 A	1.01	GENESEE		1.00 N		-3.00	BATAVIA - BERGEN	386.24 U			400	100				RURAL
386.29 A	0.45	GENESEE		0.00		3.00	NYCRR (MAIN)	386.85 U			400	100		388.7		RURAL
386.74 A	1.04	GENESEE		0.75 S		3.00	FOTCH RD	387.18 O			400	80		387.0		RURAL
387.78 A	1.95	GENESEE		0.00		-1.00	BANK ST	388.73 U			400	80		389.7		RURAL

Table 2-1. Database Sample.

VHSR Existing Railroad Corridor

The existing railroad alignment in the corridor, which is about 464 miles long, is owned by the Metro-North Commuter Railroad (MNCR) from Manhattan to Poughkeepsie, and by Conrail from Poughkeepsie to Niagara Falls with the exception of a ten mile segment owned by Amtrak from Schenectady ten miles west. Amtrak provides long-distance and regional passenger service (called Empire Service within New York State) over the entire route using trackage rights agreements with the other owners. Conrail operates freight service over the other owners' track as well, and also has parallel freight-only lines between Albany and the New York City area. Metro-North operates extensive commuter service south of Poughkeepsie.

This section summarizes the existing conditions in the railroad corridor; additional information and mapping is given in Appendix 2A. Curvature variations for the rail corridor are shown in Figure 2-2. Land-uses in the areas adjacent to the corridor are largely rural (58 percent of the route). The rail corridor passes through more suburban and industrial areas than the Thruway corridor. The mileposts, that are usually typically equivalent to Conrail designations, increase from east to west except in the Niagara Falls area.

It should be noted that the existing rail corridor is primarily owned by Conrail and the commuter railroads. This study assessed only the technical potential of achieving high-speed passenger service in the corridor. A variety of institutional, legal, and regulatory issues would have to be resolved prior to the implementation of such service in the corridor. It is Conrail's current position that speeds in excess of 90 mph are not compatible with freight operation in the corridor.

Niagara Falls to Albany.

The Conrail Buffalo to Schenectady portion of the route currently has heavy rail operations, with up to 40 or more freight and Amtrak trains daily. The location of existing trackage and the width of the ROW on this busy corridor are positive features of this long, 320-mile segment. The route previously accommodated four parallel tracks, two of which remain as active main tracks. These active tracks are generally located on the south side of the ROW thus freeing the northern part of the 66 to 125 foot rail ROW for a new rail alignment. This new rail might be dedicated to a new HSGT system or to new trackage for Conrail, with the southern most tracks improved for HSGT. The later option is posed in recognition of the fact that current freight yards are on the northern

side of the ROW and passenger stations on the southern side. Such an arrangement would therefore reduce crossovers. It is also noted that Sprint and ATT have recently installed fiber optics cables on the northern side of the ROW, these would have to be relocated in the event that new tracks were installed.

The existing alignment in the western part of the State is well-suited to an HSGT system, since it is largely tangent with light gradients. Heavier curvature does exist in the CBD areas of Buffalo, Rochester, and Syracuse, and the Niagara Falls to Buffalo segment has a relatively large number of restrictions including narrow ROW, highway structure and building restrictions, and heavy curvature. The entire route includes highway grade crossings at frequent intervals. Sensitive natural areas and wetlands could be affected; for example, the alignment crosses the Seneca River in the Montezuma National Wildlife Refuge where soil conditions also make construction and maintenance difficult. In general, the alignment from Rochester to Syracuse involves relatively tight curvature and grade crossings. This, along with the Montezuma National Wildlife Refuge may limit the potential high speed operation on this segment.

Traveling east of Syracuse to Utica, the rail ROW is generally straight with excellent high speed potential. The 75-mile segment from Utica to Schenectady where the route follows the Mohawk River valley presents the greatest challenges to high-speed operations. Here speed limits may be 125 mph, not 150 mph, as assumed in the performance simulations discussed later. High degrees of curvature and the narrow, steep valley limit speed and make realignments potentially disruptive to the relatively narrow valley and towns located there.

The Schenectady to Albany segment, currently permits speeds of up to 110 mph for passenger trains, and does not present significant obstacles to higher speeds.

Albany to Northern New York City Suburbs.

The railroad alignment from Albany to the northern New York City suburbs also accommodated four tracks at one time, and currently contains two or more tracks over its length. The typical ROW for this part of the corridor is approximately 66 feet wide.

Intercity passenger rail service on this 100-mile segment is operated by Amtrak. Conrail provides rail freight service usually in the evening and night hours. Metro-North commuter trains operate on

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the segment south of Poughkeepsie. Very little freight service is provided between Schenectady and Hudson, a stretch of track currently under consideration for a demonstration of 125 mph service.

Figure 2-2. Curvature Variation for Existing Rail Alignment.

This segment is limited topographically, making significant realignment difficult without major environmental, residential, and commercial impact. The alignment includes many long reverse curves because it runs along the eastern bank of the Hudson River. Along much of this corridor, the land to the east of the Hudson is hilly with high, steep slopes immediately adjacent to the river. The railroad alignment hugs the shoreline at the base of these hills, outlining the river's edge. Numerous wetlands and other watered areas are adjacent to the ROW.

Northern New York City Suburbs to New York City.

The alignment from north of Tarrytown south to Spuyten Duyvil in the Bronx is owned by MNCR and operated as the Hudson Line. The two track line expands to three main tracks near Peekskill, and four at Croton-Harmon. The entire route previously had at least four tracks, so additional space is generally available where there are fewer than four tracks. The line lies within a confined ROW, with the Hudson River to the west and urban development to the east. The opportunities for significant realignment of restrictive curves on this line are extremely limited and costly due to the Hudson River, industrial areas, residential areas, and numerous reverse curves. Existing station platforms are also obstacles to new construction. A typical configuration has two platforms for local tracks along the outside of the facility, with express tracks in the center.

A railroad junction is located at Spuyten Duyvil in the South Bronx, where Metro-North tracks head east and south to Grand Central Terminal. The 10.8-mile Amtrak West Side Division crosses the Harlem River at Spuyten Duyvil and extends to Manhattan's Pennsylvania Station. The line, adjacent to the Hudson River, was recently rehabilitated to provide Amtrak access to Pennsylvania Station from Albany and beyond. The route often parallels highways or parkland, and realignment would be difficult and potentially very expensive. The ROW is often elevated, or is overbuilt with buildings and highway structures. Near West 60th Street the ROW narrows, with clearance only for the two existing tracks serving Pennsylvania Station.

Maglev Thruway Corridor

The NYSTA is a controlled-access toll road, also designated Interstate 90, 87, and 287, which extends along a corridor from Buffalo to Albany, then south on the west side of the Hudson River. The Hudson near Tarrytown, then runs south through Westchester County to connections with other highways in the Bronx. The fenced ROW usually includes four to six traffic lanes, a median ranging

up to several hundred feet, and varying widths of adjacent open space on each side of the roadway. The total ROW width, often 300 feet or more, is wider than that of the railroad corridor.

Curvature of the usable portion of the Thruway corridor is summarized in Figure 2-3. The areas adjacent to the corridors are largely rural (73 percent of the route).

Niagara Falls to Albany.

The Thruway does not serve Niagara Falls. It continues southwest from Buffalo toward Pennsylvania and Ohio. The western segments of the Thruway, with relatively gentle curves and long tangents, are well-suited to an HSGT system. The Thruway bypasses Rochester about nine miles south of the CBD. An alignment in this corridor does not encounter significant curvature until the Phelps area, about 30 miles east of Rochester. There are also increased curvature and narrow ROW restrictions near central Syracuse.

The Thruway shares the Mohawk River valley between Utica and Schenectady with the Conrail alignment. The segment is subject to the same vertical and horizontal restrictions and curve limitations as the railroad corridor. Any proposed curve modification will affect adjacent areas, sometimes severely.

Albany to Northern New York City Suburbs.

This segment, parallel and several miles west of the Hudson River, generally avoids developed areas. The corridor enters the New York City area from the north via a narrow valley through the Ramapo Mountains. Near the New Jersey state line at Suffern, the alignment turns east, crosses over the Hudson River on the Tappan Zee Bridge near Tarrytown, then continues south. From the Garden State Parkway (Interchange 14) to the Tappan Zee Bridge, the New York State Thruway is a six-lane Interstate.

Northern New York City Suburbs to New York City.

The center median and overall ROW width decreases significantly as the metropolitan area is approached. Curvature also increases, and crossing structures become more complex and numerous. The Thruway and its connecting highways are unsuitable for HSGT in the New York City area.

Figure 2-3. Curvature Variation for Existing Thruway Alignment.

ALIGNMENT METHODOLOGY FOR MAGLEV AND VHSR

The proposed alignment layout used USGS Quadrangle Maps at a scale of one inch to 25,000 feet. Curve characteristics were also estimated for the Thruway corridor using these maps. The existing railroad and Thruway alignments from New York City to Niagara Falls are shown in Figure 2-1. Larger-scale maps of the alignment are shown in Appendix 2A in Figures 2A-2 through 2A-11.

Initial investigations indicated that both railroad and Thruway alignments have potential for HSGT. These investigations found the railroad alignment particularly suitable for a steel wheel VHSR system because:

- VHSR technology applied along the existing railroad route could take advantage of the infrastructure such as existing grade separations;
- Previously abandoned track along large segments of the corridor could provide the space required;
- Relatively low gradients and other operational requirements such as power, signals, and control are compatible;
- The grade separation of existing highways for at-grade VHSR would provide additional public benefit by eliminating the crossing hazard of the parallel existing freight railroad as well; and
- Although a new rail line could often operate close to the Thruway, the complexity of at-grade construction within the existing ROW is complicated by numerous overpasses and interchanges requiring designing and constructing numerous grade separations at each interchange and overpass at significant cost.

For these reasons we have elected not to pursue VHSR on the Thruway ROW.

The advantages outweigh the disadvantages of VHSR on the railroad alignment, which includes complex and potentially costly liability and property negotiations with private railroads, impeded rail access to adjacent shippers, and safety concerns.

The railroad alignment also has a few characteristics suitable for a Maglev system; however, the Thruway was preferable for Maglev because:

- To handle the required changes in vertical geometry elevation, and for safety reasons, the Maglev system is assumed to be elevated. The steeper gradients of the Thruway, and the complex interchanges and bridges on the Thruway would be best negotiated by an elevated Maglev system;
- Although the envelope of a dual-guideway Maglev requires 35 to 40 feet, the footprint of the elevated structure is much smaller, providing flexibility in locating support members; and
- The Thruway ROW is already under public control, minimizing negative impacts on private interests, including the freight railroads, easing liability complications, and maximizing design flexibility.

For the above stated reasons, the corridor investigation was divided based on technology, with Maglev technology on the Thruway route, and VHSR technology on the existing railroad corridor. For any technology, the shared use of ROW will require careful evaluation of safety, construction and liability issues. Coordination with operating and regulatory agencies, such as the Federal Railroad Administration and the various highway authorities, also will be important.

Performance Simulations

A methodology using the Railway Operations Network Simulator, a computer-based simulation of HSGT system performance over a defined alignment, was developed for evaluating performance on existing and improved alignments.

- Alignment parameters including horizontal and vertical curvature characteristics, superelevation, maximum and limiting speeds; and
- Equipment performance parameters for each technology included acceleration rates, braking rates, lateral acceleration limits, tilt capability, maximum speeds, and consist characteristics.

The simulations included seven station stops shown in Table 2-9 with the exception of Albany, where the station site was Rensselaer. Dwell time at all intermediate stations was one-and-one-half minutes. On-line stations stops were assumed for the incremental rail improvement and VHSR options. Maglev is assumed to have switches to off-line stations thereby allowing express service.

The resulting train performance calculations (TPCs) generate speed profiles, average speeds, travel times, and energy consumption estimates over the alignments length. Appendix 2-B, Volume 4, includes detailed graphic printouts for the various TPC runs.

The following TPC calculations were made:

Baseline Alignments

TPC-A and TPC-B - Existing railroad alignment for incremental rail improvements

TPC-1 - Existing railroad alignment with VHSR technology

TPC-2 - Existing Thruway alignment with Maglev technology

Non-disruptive Modified Realignments

TPC-3 - Railroad realignment with VHSR

TPC-4 - Thruway realignment with Maglev

Aggressive Realignment

TPC-5 - Railroad realignment with VHSR

TPC-6 - Thruway realignment with Maglev

Train Performance Assumptions.

The train performance calculator uses the alignment characteristics developed for an alternative together with a set of vehicle characteristics appropriate to that alternative, and runs a computer simulation of the train operations. Provided that the TPC is loaded with appropriate resistance and acceleration data, VHSR and Maglev performance is simulated. As used in these discussions, "trains" can be Maglev vehicles or VHSR train sets (locomotives plus cars).

Assumptions regarding lateral acceleration, jerk and roll rates are based on existing acceptable levels despite recent consideration that these levels potentially could be changed to enhance performance of a Maglev system. Tests are planned to validate acceptable levels for rider comfort and to develop new criteria, where appropriate.

Input Data. For the baseline conditions, station stops were assumed at major cities along the route as a worst case scenario for calculated travel times. Express operations using off-line stations would improve the times reported in the following simulation data.

In the alignment task, the actual or proposed horizontal curvature at every point on the alignment is known. The actual or proposed superelevation or bank angle of the track is also known. In addition, the allowable unbalanced superelevation ("unbalance") of the vehicle is assumed. In this study, VHSR vehicles are assumed to be non-tilting; a corresponding unbalance of four to five inches was conservatively chosen except in TPC-7. In TPC-7, a tilt body VHSR was assumed, and a nine-inch unbalance was used.

The Maglev vehicles are assumed to incorporate 12-degree tilt bodies and a correspondingly large effective superelevation results. TPC-4A, representing a Transrapid TR07, is an exception. These superelevations and traditional comfort criteria were combined to produce the maximum speed allowable at each actual or proposed curve on a given alignment. Although in most cases it has a negligible effect on train performance, vertical curvature or gradient was analyzed for each of the proposed alignments.

Train data for the VHSR case were based on a second-generation TGV, similar to the TGV-*Atlantique*, in a 1-8-1 configuration with an allowed maximum speed of 200 mph. The Maglev data are based on a Transrapid TR07 design prototype, using a five-car consist and a maximum allowable speed of 300 mph. The technical data for these trains are described in detail in Section 1.

The tilt-train run (TPC-7) was based on a hypothetical train consisting of updated RTL power cars and ABB X2000 coaches in a 1-5-1. Each proposed RTL power car contains a single TF40 4000 HP (input) gas turbine. The RTL power car and the X2000 coaches are assumed to have increased weight from structural modifications to meet American buff- strength requirements. Estimated tractive effort for the updated RTL power cars was obtained from the manufacturer. Since these cars have not been fully designed, and there are no wind tunnel test data, train resistance values were estimated based on the consultant's judgement.

Train Performance Calculations.

An extremely large speed table of more than 2000 lines characterizes the corridor between New York City and Niagara Falls due to the incidence of more than one curve per mile on average, frequent changes in gradient, and overall length. Furthermore, the alternating nature of tangents and curves, when closely spaced, means that maximum operating speeds cannot be reached in many cases. To simplify the speed tables, gradients of less than 0.4 percent were assumed to be zero; the limiting speed for each curve was modified by pre-simulation which effectively discarded many of the non-achievable limiting speeds and replaces them with lower, more realistic speeds from adjacent segments.

The assumptions used in the pre-simulation process were conservative to prevent loss of performance, safety, or accuracy. Note, however, that even after modification, the speed tables may contain unachievable limiting speeds. Further, in the interests of time and effort there was no attempt to smooth the TPCs to produce a simple speed profile (simple to operate), nor was an attempt made to limit the energy consumption implicit in the aggressive speed profiles simulated. In addition, the speeds in station areas were manually reduced by severely limiting the amount of achievable superelevation and unbalance. The same approach limited sharp-curve elevation. The pre-simulation process produced a set of speed tables appropriate for simulation without having to develop a smoothed speed table, a time-consuming iterative process.

The TPC results produce the lower limits of trip times, rather than published schedule times. Actual train schedules would be based on more detailed "smoothed" TPC runs, and include recovery time, schedule slack, or similar allowance that would be needed for reliability. In an energy sense, the values from the TPCs are also limiting because they represent maximum values of energy consumption for the proposed alignments and vehicle consists. Less aggressive speed profiles would consume somewhat less energy than the amounts calculated.

Train Performance Results.

TPC output includes three reports for each simulated alignment. These can be found in the data appendices to this report. The reports include:

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- A detailed report showing train location, speed, speed limit, traction and brake forces at ten-second intervals;
- A summary report showing the station list and elapsed times, maximum and average speeds, and overall energy consumption for each run; and
- A plot of speed compared to distance for each run showing location, station name, speed limit, and actual train speed. These plots contain 24 miles of route per letter-size page.

Table 2-2 shows key assumptions used in the TPCs.

Table 2-2. Key Assumptions Used in VHSR Performance Runs.

Rail	Tilt	Max. Speed (mph)	Actual Super- elevation	Unbalanced Elevation	Total Elevation	Consist	Type
TPC-1	No	200	4 in	4 in	8 in	1-8-1	TGV-A
TPC-3	No	200	6 in	5 in	11 in	1-8-1	TGV-A
TPC-5	No	200	6 in	5 in	11 in	1-8-1	TGV-A
TPC-7	Yes	150	4 in	9 in	13 in	1-8-1	RTL-TF X2000
Maglev	Tilt	Max. Speed (mph)	Bank Angle	Vehicle Tilt	Total Bank	Consist	Type
TPC-2	Yes	300	12 deg	12 deg	24 deg	5	TR-07
TPC-4	Yes	300	12 deg	12 deg	24 deg	5	TR-07
TPC-4A	No	300	12 deg	0 deg	12 deg	5	TR-07
TPC-6	Yes	300	12 deg	12 deg	24 deg	5	TR-07

In addition to the guideway and vehicle and angles provided, curve speeds were set to provide 0.1 g lateral acceleration in each Maglev run, roughly equivalent to the VHSR runs. Allowance of higher lateral acceleration would produce high average speeds but require passengers to remain seated.

Incremental Rail Improvements

Alignment Criteria and Assumptions. The criteria and assumptions used to analyze alignments for incremental improvements to the current rail service are based on existing rail alignment, maximum speeds, and superelevation. Horizontal curvature and existing grade crossings are the most critical elements that affect speed along the existing corridors. Since incremental improvements can vary widely, some general assumptions were made when comparing this service with VHSR and Maglev. No curve realignment or electrification was included.

Several significant interface issues will require investigation and negotiation with the railroads owning the ROW to operate this type of service over existing trackage, especially where heavy and frequent freight operations continue. Coordination issues will include cab signaling and train/vehicle control, physical track-parameters such as underbalance (waived FRA requirements will likely be necessary), and cost allocation. Institutional issues related to liability and safety will be difficult to overcome. It is clear that the railroad owning the ROW has extraordinary concerns regarding both sharing existing trackage and existing ROW with travel dedicated to high-speed passenger service. If it is determined that there is no practical and safe means to operate a dual-track 150 mph passenger service and freight service on a common ROW, the upper limit of incremental passenger service found to be technically feasible in this study may not be achievable.

Results of the TPC Runs for Incremental Rail Improvements. TPC results for incremental improvement on the railroad alignment are summarized in Table 2-3. The table shows that trip times following improvements are significantly reduced from current Amtrak Pennsylvania Station to Niagara Falls trip times of over eight and one-half hours.

Table 2-3. Incremental Performance Simulation Summary.

Existing Railroad

	Name	Alignment	Avg. Speed (mph) (incl. stops)	Trip Time (Hours:Min)
TPC-7	Incremental	Existing Rail	99.3	4:40
TPC-7	Incremental	Existing Rail		4:24:30

VHSR

Alignment Criteria and Assumptions.

Horizontal curvature, potential ROW, and existing grade crossings were the most critical elements along the existing corridors. As previously discussed, the existing railroad corridor was evaluated for VHSR use together with the criteria and assumptions shown in Table 2-2.

The initial step was selecting a preferred minimum horizontal curve radius for VHSR systems. For VHSR systems, the minimum radius was 15,000 feet, based on the maximum desirable speed of 200 mph, with a maximum total actual and unbalanced superelevation of 11 inches.

The typical maximum desirable gradient for VHSR has been assumed to be about four percent which compares favorably with gradients on the existing railroad ROW, generally under one percent. The gradients are unlikely to pose limitations. However, transitions between gradients will be important design criteria, since these transitions can be very long, depending on vehicle design speed.

A VHSR system is assumed to incorporate dedicated trackage; existing Conrail/Amtrak/Metro-North restrictions on curve superelevation and other parameters generally are not applicable except in confined areas such as tunnels. Coordination with other regulatory agencies will be required for issues including cab signaling and train/vehicle control and track-safety issues.

Provisions must be made for freight railroad yard and industrial spur trackage affected by a parallel VHSR system. All analyses, elevations, and estimates assume complete grade separation by consolidation or relocation. Though clearly desirable, this may be impractical or may not be cost-effective in all instances. There may be a need for freight railroad operations to cross VHSR trackage at grade at selected locations to preserve service to adjacent local industries. This may be possible late at night when no high-speed service is operated. This and other interface issues will require investigation and negotiation with the railroads, shippers, local officials, the Federal Railroad Administration (FRA) and others.

The required ROW width for a double-track, VHSR system was assumed to be 60 to 80 feet, depending on topography, size and design of slopes and ditchlines, and adjacent restrictions. The shared use of an existing railroad ROW will require evaluating a minimum physical separation, or providing barriers/crash walls. The investigation of existing ROW width also identified other issues

and restrictions including buildings, roadways, and other congestion in urban areas; and waterways, wetlands, and natural topography, such as rock cuts, in rural areas.

Inputs to the model include:

- **Alignment parameters, including horizontal and vertical curvature characteristics, superelevation, maximum and limiting speeds;**
- **Equipment performance parameters for French TGV-A technology included acceleration rates, braking rates, lateral acceleration limits, maximum speeds, and consist characteristics; and**
- **The simulations included seven station stops shown in Table 2-9 with the exception of Albany, where the simulated station site was Rensselaer. Dwell time at all intermediate stations was one-and-one-half minutes.**

The resulting Train Performance Calculations (TPCs) include speed profiles, average speeds, travel times, and energy-consumption estimates. Appendix 2-B Volume 3, includes detailed graphics for the various TPC runs for the full length of the alignment. Figure 2-4 is a sample speed profile over a small segment of the alignment. The squared-off trace in the figure indicates the speed limit, and the jagged trace indicates simulated speed at each point on the route. Speed profiles along alignments are calculated for each segment of the route to identify critical curve groups that limit speed. Modifications to these groups are made in the corridor alignment to improve performance.

**Figure 2-4. Sample TPC Speed Profile Taken from Appendix 2, Volume 4,
Showing a Station Stop at Rochester.**

VHSR Alignments.

Baseline Alignment (TPC-1). The existing railroad ROW alignment was approximated to generate the baseline to compare the performance of a modified, realigned VHSR alignment. TPC-1 approximates an electrified high-speed system basically using existing ROW, making certain approximations and calculations about characteristics such as available spiral lengths and superelevation. This TPC-1 also assumes that the existing railroad facilities could be easily relocated within the ROW to maximize VHSR speeds. Due to these inaccuracies, TPC-1 is not a competitive or realistic alignment option, but is used as a baseline for speed profiles indicating severe speed limitations and what grouping of curves could be modified for increased speed.

Non-disruptive Realignments (TPC-3). TPC-3 is a proposed VHSR alignment that leaves the existing ROW in a non-disruptive manner to achieve higher speeds. Horizontal curves and corresponding superelevation are improved. Consideration was given to spiral lengths, particularly in reverse curves within existing environmental restrictions. Attempts were made to avoid:

- Residential, commercial, and other developed areas;
- Sensitive areas, including rivers and wetlands; and
- Areas where difficult and costly construction such as large cut/fill requirements and river encroachments would be necessary because of natural conditions.

Use of existing ROW is maximized, though curves are realigned somewhat more aggressively. If the curves within a 10-mile to 20-mile segment can be reduced, higher speeds may be maintained over a longer distance, thereby gaining the most speed for the cost of the aggressive relocation.

Major changes in the alignment often are difficult due to the required, but limited superelevation transitions between curves. In many cases when improvements to one curve were considered, several adjacent curves were affected. When a several-hundred-foot-length curve was initially reviewed, a total realignment length of several thousand feet resulted after applying proper transition lengths.

Aggressive Realignment (TPC-5). TPC-5 is a more aggressive, unrestrained alignment that maximizes using the existing ROW in heavily developed or environmentally sensitive areas. Aggressive realignments were estimated using these criteria:

- The alignments lie within existing ROWs where possible; however, horizontal curves are adjusted, and superelevation increased maximum speed over as much of the routes as possible;
- A less restrictive social and environmental impact policy;
- A relatively aggressive use of tunneling and major earthwork, accepting certain environmental and social impacts and higher construction costs where running time improvements result; and
- Multiple Thruway and river crossings are assumed when necessary.

The 75-mile segment from Utica to Schenectady (Appendix Figures 2A-5, 2A-6, and 2A-7), where the route follows the Mohawk River valley, challenges high-speed operations. One of the most significant realignments proposed by TPC-5 is near Herkimer, east of Utica near Milepost 220, where 10 miles are relocated to the south side of the Mohawk River valley, largely on an abandoned railroad ROW. Several other significant realignments are proposed near Fonda, west of Amsterdam near Milepost 180.

Figure 2-5 illustrates a proposed aggressive corridor realignment. This particular alignment just east of the Lyons area allows an increase in speed from about 60 mph to 115 mph for the aggressive case. Higher speeds could be accommodated on this segment if the industrial buildings inside the curve at the lower left of the figure could be removed. Figure 2-6 shows the frequency and degree of curvature modification along the rail corridor for non-disruptive and aggressive realignments. This figure indicates curve changes and shows the extent of realignment, not the curvature of the route after realignment. Increases in curvature reflect the lengthening of curves onto adjacent tangents, which is required when decreasing the degree of curvature.

Figure 2-5. Sample Aggressive VHSR Realignment.

Figure 2-6. Frequency and Degree of Curvature Modification along Rail Corridor.

Results of the VHSR TPC Runs

TPC results for VHSR on the railroad alignment are summarized in Table 2-4, with additional details, including travel times, between intermediate cities in Table 2-5. As noted previously, the baseline TPC-1 is not intended as an alignment option, but as a base case for comparisons. Schenectady was included as a station stop when these runs were simulated; it has since been eliminated.

Table 2-4. VHSR Performance Simulation Summary.

Railroad Corridor

TPC	Alignment	Avg. Speed (mph) (incl. stops)	NYC-Niagara Falls Trip Time (Hours:Min)
1	Baseline	86.2	5:23
3	Non-Disruptive	101.8	4:34
5	Aggressive	116.1	4:00

Table 2-4 shows trip times could be improved significantly by curve realignment. Currently Amtrak's Pennsylvania Station to Niagara Falls trip times are more than eight hours. A baseline VHSR time is 5 hours 23 minutes; non-disruptive or aggressive realignments could potentially provide a trip time from four to four-and-one-half hours. One and one-half minute station dwell times were assumed for performance calculation shown in Table 2-4.

Segments between Poughkeepsie and Utica show the largest decrease in trip time from realignment, which is expected considering the large number of realigned curves. The non-disruptive realignment decreases the time over this segment by more than 21 minutes, or 14 percent of the baseline time, while the aggressive realignment decreases the time by more than 43 minutes or 28 percent.

Using the simulation results, the express travel times between New York City and Albany and Albany and Buffalo are shown in Table 2-5.

Table 2-5. VHSR (Conrail/Amtrak/Metro-North Alignment).

Description of TPC	New York City to	Albany to Buffalo	New York City to
TPC-1 Existing	1:45	2:42	4:32
TPC-3 - Moderate	0:50	2:12	3:04
TPC-5- Aggressive	1:22	2:00	1:24

The express travel times are estimated using the performance simulation results and correcting for dwell times and acceleration/decelerations into and out of stations. Some speed reductions are still required in the proximity of stations and urban areas along the express trip.

Maglev Performance Simulations

Alignment Criteria and Assumptions

Using criteria based on current demonstrated and projected maximum speeds and superelevation, elements critical to the selection and analysis of alignments for Maglev systems are discussed below. Horizontal curvature and potential ROW were the most critical elements along both existing corridors.

For a Maglev system, the minimum horizontal radius of curvature was about 11,000 feet (3363 m), based on the maximum speed of 300 mph (480 kph), assuming that vehicles have independent banking capability (Tilt). A 0.1 g unbalanced lateral acceleration is permitted; without this tilt capability, the necessary limitation on curvature for speeds approaching 300 mph (480 kph) would prohibit using much of either the existing Thruway or railroad alignment because the curve radii required for 300-mph would be 20,000 feet or more.

Gradients on the existing Thruway alignment generally are less than three percent. Typical maximum desirable gradient for Maglev is about 10 percent. These gradients are unlikely to pose limitations, however, transitions between gradients will require investigation, since they can be very long, depending on vehicle-design speed.

Unlike the railroad corridor, the Thruway has a significantly wider average ROW width, about 300 feet. Additional ROW adjacent to the Thruway would still be required to accommodate the broad curves and long spirals required to achieve maximum Maglev speeds.

A Maglev system will require an exclusive guideway. Since the system is elevated, there is greater flexibility when selecting support structure configuration. Dual guideways are 35 feet to 40 feet wide. A center support configuration could require as little as 20 feet; a two-column full-span structure could require 40 feet (12 m) or more.

Coordination with the other regulatory agencies will be required for operation and train control, physical equipment, and infrastructure safety parameters such as underbalance. The shared use of an existing highway ROW will require careful evaluation to provide minimum physical separation and barriers/crash walls. Construction methods and staging to avoid impacting the highway are also critical.

Maglev Alignments

A 453-mile (725 km) Maglev alignment could be located mostly along the Thruway ROW with significant exceptions at each end of the route. From Niagara Falls to the Buffalo CBD, the proposed route would use the Conrail Niagara Branch as would VHSR. This alignment is superior to Interstate 190, which, while it is located nearby, includes significant elevated and steeply graded segments.

In Tonawanda, north of Buffalo, the route would diverge onto a six-mile abandoned former Conrail ROW heading southeast to the Buffalo airport and the Thruway. This alignment was selected due to severe curvature and other restrictions on I-190, the Thruway, and Conrail through the CBD area. Beyond Buffalo, the Thruway corridor (with the guideway usually on one side of the ROW) was identified for use, though there may be opportunities to use parallel abandoned railroad ROWs, especially between Buffalo and Batavia.

The other major deviation from the Thruway is the entrance to the New York City area. Based on an analysis of alternate routes, the preferred alignment to Pennsylvania Station would diverge from the Thruway immediately east of the Tappan Zee Bridge onto the Metro-North railroad ROW at Tarrytown. This would provide a relatively direct connection to the Thruway alignment, and would be preferable to alternate highway or other rail routes, though this would require a new Hudson River bridge parallel to the existing Tappan Zee Bridge due to structural limitations of the existing bridge. The Metro-North and Amtrak route could then be used from Tarrytown to Pennsylvania Station.

As discussed for VHSR, a computer-based simulation of Maglev performance over a defined alignment was used for evaluating and rating curve realignments and other improvements.

Baseline Alignment (TPC-2). A Maglev alignment on the existing Thruway corridor was approximated, without increased ROW but also without considering impacts on the Thruway, to determine baseline speeds and travel times. Again, competitive or realistic performance was not expected from this baseline approximation; it is used only for comparison.

Non-disruptive Realignment (TPC-4). Realignment methodology is similar to VHSR, with "environmental" restrictions that minimize impact to existing natural and developed areas.

This alternate requires approximately 12% of the Maglev system to deviate from that of the existing highway.

Aggressive Realignment (TPC-6). The methodology for TPC-6, the aggressive realignment, is also similar to the VHSR aggressive case. One additional issue is the number of crossings of the Thruway traffic lanes. To accommodate Maglev's high maximum speeds, the most attractive horizontal alignment includes many gradual curves that would require multiple crossings of the Thruway traffic lanes as well as rivers, in some areas. This alternative requires approximately 58 percent of the Maglev system to deviate from that of the existing highway alignment.

Besides being costly, this arrangement increases construction and maintenance disruptions, and may affect highway users' sight distances and perceptions.

Figure 2-7, a proposed aggressive realignment of the Thruway corridor, shows that changes to the Thruway curves are sometimes relatively small in terms of lateral realignment distance, but significantly impact existing conditions with four highway crossings. Additionally, bridging structures costs are relatively high due to the lengthy spirals and small degree of curvature Maglev speeds require. Careful engineering evaluation and design will be required to minimize multiple crossovers above the Thruway.

Figure 2-8 shows the frequency and degree of curvature realignment for Maglev along the Thruway corridor for the non-disruptive and aggressive realignments. Figure 2-9 summarizes existing and proposed curvature in the number of curves and lengths of curves proposed for realignments. Note that increases in curvature generally lengthen the curves onto adjacent tangents to decrease the degree of curvature, rather than including new curves.

Figure 2-7. Sample Aggressive Maglev Realignment.

Figure 2-8. Frequency and Degree of Curvature Realignment for Mayle along Thruway Corridor.

Figure 2-9. Total Curve Length and Degree of Curvature Modification along Thruway Corridor.

Results of the Maglev TPC Runs

Table 2-6, showing Maglev trip times, reflects a relatively small difference between both baseline and non-disruptive times, and between non-disruptive and aggressive times, partly because at relatively high speeds, fairly major realignments have less effect on trip times. Note that the baseline TPC-2 contains bank-angle and spiral-length assumptions to approximate a guideway geometry lying within the ROW, but does not consider traffic lane relocation or number of overhead crossings of the traffic lanes by the guideway.

An additional factor that affects the speed of a Maglev vehicle is tilt. Two TPC runs were performed on the non-disruptive realigned Thruway to demonstrate the effect of a tilting Maglev vehicle on speed and travel times. The results, shown in Table 2-6, indicate that tilt capability significantly improves the speeds and travel times in this corridor, saving about 20 minutes on the non-tilting Maglev system.

Table 2-6. Maglev Performance Simulation Summary.

Thruway Corridor

TPC	Name	Avg. Speed (mph) (incl. stops)	NYC-Niagara Falls Trip Time (Hours:Min)
2	Baseline	158	2:52
4	Non-Disruptive w/tilt	174	2:36
4a	Non-Disruptive No-tilt	155	2:55
6	Aggressive	187	2:25

Table 2-7 shows city pair trip times for each Maglev TPC for sequential station stops at each city along the corridor. Table 2-8 shows estimated express trip times between New York City and Albany and then Albany to Buffalo. These trips times are estimated based on the results of the performance simulations by eliminating the dwell times at stations and the times for acceleration and decelerations. In the vicinity of the stations, curve realignments generally are more constrained by heavier development in the segments between cities. In the case of the Maglev system this may not be as much of a constraint in a newly constructed right-of-way but should still be considered in these estimates.

One of the benefits of a Maglev system's operating a greater number of smaller vehicles is the expanded ability to take advantage of off-line stations to provide "customized" service between city pairs. The off-line stations eliminate the numerous stops normally made by conventional rail systems using on-line stations configurations. Theoretically, Maglev can provide express service between any two city pairs in the corridor.

Table 2-7. VHSR and Maglev TPC City Pair Performance.
(Times include Intermediate Stations Stops)

VHSR (CONRAIL/AMTRAK/METRO-NORTH ALIGNMENT):

STATIONS	ELAPSED DISTANCE (MILES)	TPC-1 BASELINE			TPC-3 NON-DISRUPTIVE			TPC-5 AGGRESSIVE		
		STATION TO RUNNING TIME (MIN)	RUNNING SPEED (MPH)	MAXIMUM SPEED (MPH)	STATION TO RUNNING TIME (MIN)	RUNNING SPEED (MPH)	MAXIMUM SPEED (MPH)	STATION TO RUNNING TIME (MIN)	RUNNING SPEED (MPH)	MAXIMUM SPEED (MPH)
PENN STATION NYC										
TARRYTOWN	24.70	23:23	63.4	109.9	20:27	72.5	122.0	19:42	75.2	122.0
POUGHKEEPSIE	72.65	40:18	71.4	122.3	34:19	83.9	132.0	29:35	97.3	145.5
ALBANY	141.24	45:39	90.1	143.3	40:21	102.0	156.4	36:42	112.1	170.6
SCHENECTADY	158.90	14:49	71.5	165.5	13:12	80.3	176.3	12:46	83.0	177.1
UTICA	236.60	51:31	90.5	131.0	42:37	109.4	178.8	29:58	155.6	196.6
SYRACUSE	290.64	31:23	103.3	161.3	22:33	143.9	200.0	21:15	152.5	200.0
ROCHESTER	370.14	48:19	98.7	171.9	40:30	117.7	200.0	36:12	131.8	200.0
BUFFALO	437.42	31:31	128.1	200.0	28:17	142.7	200.0	25:04	161.0	200.0
NIAGARA FALLS	464.40	24:14	66.8	129.3	19:21	83.7	149.8	16:43	96.8	163.5

MAGLEV (NEW YORK STATE THRUWAY ALIGNMENT):

STATIONS	ELAPSED DISTANCE (MILES)	TPC-2 BASELINE			TPC-4 NON-DISRUPTIVE			TPC-6 AGGRESSIVE		
		STATION TO RUNNING TIME (MIN)	RUNNING SPEED (MPH)	MAXIMUM SPEED (MPH)	STATION TO RUNNING TIME (MIN)	RUNNING SPEED (MPH)	MAXIMUM SPEED (MPH)	STATION TO RUNNING TIME (MIN)	RUNNING SPEED (MPH)	MAXIMUM SPEED (MPH)
PENN STATION NYC										
TARRYTOWN	23.78	13:04	109.2	197.7	12:38	112.9	197.6	10:55	130.7	243.1
KINGSTON	103.61	30:45	155.7	241.8	28:25	168.5	255.2	23:16	205.8	300.0
ALBANY	158.55	21:15	155.1	236.4	20:52	158.0	236.5	18:01	183.0	300.0
SCHENECTADY	164.55	3:49	94.2	178.4	3:47	95.0	187.5	3:48	94.9	187.5
UTICA	243.55	27:33	172.0	266.9	23:13	204.2	300.0	21:59	215.7	300.0
SYRACUSE	293.25	15:14	195.7	300.0	13:12	226.0	300.0	13:12	226.0	300.0
ROCHESTER	374.50	22:46	214.2	299.8	19:36	248.7	300.0	19:37	248.6	300.0
BUFFALO	430.03	15:24	216.3	300.0	14:11	234.9	300.0	14:11	235.0	300.0
NIAGARA FALLS	452.80	9:59	136.9	223.8	8:23	162.8	235.3	8:23	163.0	235.3

Table 2-8. Estimate of Maglev Express Trip Times Savings.

TPC	New York City to Albany Express	Albany to Buffalo Express	New York City to Buffalo Express
2	1:00	1:06	2:08
4	0:57	0:56	1:55
6	0:50	0:53	1:45

Travel times for the express runs are estimated from the performance simulations by eliminating dwell times in the intermediate stations, correcting times for acceleration and deceleration at station stops, and assuming average speed on either side of station along the segment. Maglev express trips were estimated assuming an alignment bypassing Schenectady or Amsterdam. Estimates corrected travel times by accounting for dwell times and acceleration/deceleration on the approach and exiting stations.

NEW YORK CITY ACCESS

Special attention was given to accessing New York City from its northwestern suburbs. Identifying new HSGT alignments, or realignments to existing alignments, is difficult due to unusually dense development and major natural barriers including the Hudson and other rivers. Because alignment deviations are difficult, selecting potential alignments is largely a function of terminal station location. For these reasons, potential terminal sites were identified first, followed by evaluating available ROW. A New York City Terminal Station will require new structures, a bridge or tunnel to cross the Hudson River and will require coordination with existing transportation entities, such as Metro-North, and Conrail, to gain use of portions of the existing ROW or slots for access to Pennsylvania Station or other rail facilities. An expanded summary appears in Appendix 2.

Four terminal locations were considered: Pennsylvania Station and vicinity (Manhattan); Grand Central Terminal (Manhattan); Sunnyside Yards (Queens); and Secaucus (New Jersey). These potential terminal locations and route alignment options are shown in Figure 2-10.

Terminals were evaluated for:

- CBD access;
- Accessibility to local and regional transportation systems;
- Future economic development potential; and
- Future potential for HSGT system extensions on other routes.

Pennsylvania Station

Located in Manhattan at 32nd Street and Seventh Avenue, Pennsylvania Station, or its vicinity, was recommended for the HSGT terminal for these reasons:

- Midtown location is convenient to many Manhattan destinations;
- Direct connections available to local and regional transportation network, with numerous system improvements planned for connecting services;
- Additional travel services available from nearby Grand Central Terminal, Port Authority Bus Terminal, and regional airports via local mode transfers.

Figure 2-10. Potential New York City Terminals and Alignments.

Additional considerations include:

Amtrak. Pennsylvania Station is served by Amtrak's Northeast Corridor main line, providing local and express service to Washington, Boston, and intermediate points, and by Amtrak's West Side Division, providing service to the Hudson River valley, Albany, and beyond. There is extensive long-distance service along the East Coast to Florida, the Midwest, New England, and Canada, as well as upstate New York.

New Jersey Transit (NJT). Pennsylvania Station is the commuter terminal for the NJT regional network. Three lines currently terminate at Pennsylvania Station, with transfers available from other NJT lines. With the opening of new connections in New Jersey under construction and planned, additional NJT New Jersey and Rockland County (New York) lines will gain direct access to Pennsylvania Station. Several planned signalling and Hudson River tunnel projects will improve these services.

Long Island Rail Road (LIRR). The LIRR, the nation's largest commuter railroad in terms of ridership, uses Pennsylvania Station as its Manhattan terminal. The LIRR serves approximately 130 communities using an intricate Long Island network, including large and growing populations in Kings, Queens, Nassau, and Suffolk counties.

The LIRR is currently developing a network strategy to develop future alternatives. Using several growth scenarios, improvements being considered are faster service to Pennsylvania Station; greater integration of service with Nassau and Suffolk county bus service; increased parking at stations; and increased capacity into Pennsylvania Station as a result of improved signaling in the East River tunnels.

Local Transportation Links. Subway connections to the boroughs of New York City are available using the Seventh Avenue/Broadway (IRT) and Eighth Avenue (IND) subway lines. The Sixth Avenue (IND) line, the Broadway (BMT) line, and the PATH (H&M tubes) trains to New Jersey are a one-block walk east of Pennsylvania Station.

Future Improvements. A current study is evaluating alignments for transit service to LaGuardia and Kennedy airports, including a possible connection with the Long Island Rail Road. This Automated Guideway Transit (AGT) System study was commissioned by the Port Authority of New York and New Jersey. The AGT system will provide service to Pennsylvania Station through transfers.

Amtrak is currently considering alternatives for relieving train and passenger conditions at Pennsylvania Station, including using the adjacent post office building. The current Pennsylvania Station facility clearly does not have the capacity to handle the additional demands of an HSGT system, so an alternate/expanded configuration is necessary. Alternative locations in the Pennsylvania Station vicinity also may be worthy of consideration. This study cannot adequately address this complex issue; however the Pennsylvania Station location generally has sufficient advantages to warrant selection as a HSGT terminal.

Access Routes to Pennsylvania Station. Access from the existing New York State railroad and Thruway corridors to Pennsylvania Station is most feasible using the Metro-North Hudson Line to Spuyten Duyvil and the Amtrak West Side alignment along the Hudson River. A connection with the Thruway corridor might be made using the Tappan Zee Bridge at Tarrytown. The HSGT system's use of the west approach tunnel to Pennsylvania Station is not necessarily assumed. Alternative solutions for this issue include:

- Replacing of one or both railroad tracks in the existing tunnel with a Maglev guideway;
- Additional new tunneling along all or portions of this segment; and
- Alternate station locations in Manhattan short of Pennsylvania Station, including the former Pennsylvania Central Yards at 60th Street.

Further study of access into the terminal and impacts on the available terminal capacity and operations is required.

Grand Central Terminal

Grand Central Terminal, Manhattan's East Side commuter rail hub, is the terminal for Metro-North Commuter Railroad service from northern and northeastern suburbs via the Hudson, Harlem, and New Haven Lines. Direct connections can be made to local transportation via the Lexington Avenue (IRT), Flushing (IRT), and 42nd Street (shuttle) subways, while the Seventh Avenue/Broadway (IRT) subway is one stop west via the shuttle. HSGT access from Grand Central would be provided by the Metro-North Hudson Line, which (north of Spuyten Duyvil) is common to the previously described Pennsylvania Station route via Tarrytown.

Possible future service expansions to Grand Central are being studied, including the previously mentioned Long Island Rail Road Network Strategy, which is considering LIRR access to east midtown using the 63rd Street tunnel. Possible alternate station sites have been identified under Third Avenue or in/near Grand Central Terminal, though the primary focus of LIRR service would remain at Pennsylvania Station.

Grand Central Terminal was not selected as the recommended HSGT terminal for two significant reasons. First, it can provide only limited regional access, since Amtrak, the Long Island Rail Road, or New Jersey Transit do not serve this station. Second, opportunities for HSGT expansion to the west or south are very limited since the only transportation corridor access to Grand Central is from the north.

Sunnyside Yards

Sunnyside Yards, the existing Amtrak rail maintenance facility and storage yard in Long Island City, Queens, is directly connected to Pennsylvania Station by the Amtrak Northeast Corridor, New York Division alignment. Access from Sunnyside to the existing corridors might be provided by the Amtrak Northeast Corridor to New Rochelle, then the Metro-North New Haven Division from New Rochelle to Rye, New York, then east on the Cross Westchester Highway (I-287) from Rye. The Expressway would be used west to Tarrytown and the existing corridors beyond.

This site has been considered for the development of a transportation center that would link the LIRR, Amtrak, and NJT. The Automated Guideway Transit study is also considering airport connections to this transportation center.

Sunnyside's critical disadvantage is that most HSGT trips, whether the ultimate destination is Manhattan or elsewhere in the area, would require a transfer, which would diminish any travel time saved by the high-speed system.

Secaucus

Secaucus, New Jersey, is another alternative station location for the New York City metropolitan area for an HSGT system. The site, under consideration by NJT for a possible transfer station, is east of and adjacent to the New Jersey Turnpike, just south of Interchange 16, in a largely open area of marshland near an industrial area. The New Jersey Transit Main Line and Bergen County Line,

which serve Northern New Jersey and Rockland County (NY), cross under Amtrak's Northeast Corridor route at the site.

Access from Secaucus to the existing corridors would use the ROW of the New Jersey Turnpike, I-80, the Garden State Parkway, and the NYS Thruway. The existing NJT Pascack Valley Line may have some potential for use as well. Access to the existing railroad corridor east of the Hudson River would require crossing the Hudson, likely near the Tappan Zee Bridge at Tarrytown.

The NJT lines serving the area terminate in Hoboken, New Jersey, where a PATH system transfer is required for Manhattan access. Similar to the Sunnyside site, the proposed transfer station would require connections to reach Pennsylvania Station, and would not provide connections to any other LIRR or Metro-North lines without a second transfer. Additionally, Secaucus' location is very inconvenient to Long Island.

Comprehensive technical evaluations and cost analyses were not performed, and further analysis of the complex New York City terminal issue is recommended.

POTENTIAL MAJOR CITY STATION LOCATIONS

Station locations have been proposed for all major cities, as shown in Table 2-9. Issues influencing the selection of station locations included:

- Compatibility with route alignments;
- Provisions for adequate parking;
- Satisfactory access to major highways and possibly airports;
- CBD location where alignment and operating considerations permit;
- Opportunity for connection with other intercity transportation services;
- Opportunity for connection with local and regional transit services; and
- Potential for economic development near the station.

Selecting a HSGT station site in each city has a cause and effect relationship with route alignment in that the site must be directly adjacent to or accessible from one or both of the existing corridors. Generally, station sites were considered after the corridors were identified, though in some cities more than one alignment is possible.

Stations were located in or near the CBD whenever possible, using previously mentioned criteria. In several cases, existing station sites were also desirable for HSGT. The impact of CBD locations on the route alignment can be significant, since rail access to the CBD often includes restrictive curvature, grade crossings, and limited ROW. These conditions increase construction costs and travel time while decreasing speed. In some cities, such as Rochester, a rail route is available (the West Shore Branch) that completely bypasses the center city. While this route would minimize travel time and possibly reduce construction costs, it would place the station at least five miles from the CBD, so it was not selected.

Airport access was also considered in the planning process, especially in cities (including Buffalo, New York City, and possibly Syracuse) that currently have major air facilities that could complement the HSGT system by providing intermodal connections.

Input was requested from the various metropolitan planning organizations (MPOs) along the corridor. Information describing the potential station locations was transmitted to the MPOs by the New York State Department of Transportation (NYSDOT), including background on the project, description of the planning process, and identification of potential locations. Comments were requested from the MPOs, particularly regarding any local planning issues, such as planned "transportation centers" or other local issues that could affect an HSGT system. Table 2-10 summarizes the MPO comments regarding proposed station locations.

Table 2-9. Proposed Station Locations.

Metropolitan Area	Alternative Station Locations
New York City Station	Pennsylvania Station Sunnyside Yard Grand Central Terminal Secaucus, New Jersey
North Suburban Station	Tarrytown (on the Metro-North line) Tarrytown (Van Wart) Tarrytown New Rochelle
Mid-Hudson Station	Poughkeepsie Kingston Stewart Airport
Albany	Rensselaer East Street Everett Road/I-90 Guilderland Broadway
Utica	Central Business District - Main Street NYS Thruway/I-70
Syracuse	East Syracuse Manilius Road NYS Thruway/I-81 Carousel Mall
Rochester	Central Business District/Central Avenue West Henrietta Ridgeland
Buffalo	Depew Dick Road Central Business District Exchange/Hamburg Williamsville Main/LaSalle
Niagara Falls	Hyde Park Boulevard Whirlpool Street

Table 2-10. MPO Responses to Potential Station Locations.

City	MPO	Response
Buffalo	Niagara Frontier Transportation Committee	No Response
Syracuse	Syracuse Metropolitan Transportation Council	Identified the location of a planned multi-modal transportation center, and identified a proposed rail passenger shuttle project.
Utica	Herkimer-Oneida Counties Transportation Study	Discussed the transportation center improvements at Union Station, and described site constraints at the NYS Thruway/I-790 location.
Rochester	GTC Central Staff	No Response
Albany	Capital District Transportation Committee	No Response
Poughkeepsie	Poughkeepsie-Dutchess County Metropolitan Planning Organization	Discussed the Intermodal Facility Study, a second Hudson crossing near Poughkeepsie, and a potential light rail loop connecting Orange, Ulster and Dutchess Counties.
New York City	New York Metropolitan Transportation Council	Noted the importance of a north suburban station, and referred to the potential transportation center at Sunnyside Yard. Discussed various factors related to Pennsylvania Station, Sunnyside, and the potential north suburban locations.

REGIONAL ROUTE EXTENSIONS

Overview analyses of potential extensions of the New York State high-speed system were performed for routes from Buffalo to Cleveland and Chicago, New York City to Washington, and Albany to Boston.

Western Extension from Buffalo to Cleveland and Chicago

The technical feasibility of extending an HSGT system to other regional destinations was investigated for the I-90 corridor from Buffalo to Cleveland and Chicago. About 530 miles long, this corridor generally follows the south shore of Lake Erie westward from Buffalo across western New York, northwestern Pennsylvania, and northern Ohio. I-90 continues across northwestern Ohio and northern Indiana before entering the Chicago area in the extreme northeast part of Illinois.

Existing Conditions. Except in the urban areas, the highway is generally two lanes in each direction, separated by a concrete median divider. In non-urban areas, the median is generally an open, non-paved area. The median width west of Buffalo in New York State, where I-90 is the NYS Thruway, varies considerably, ranging from less than 30 feet to more than 150 feet. The median width for the remainder of the route in Pennsylvania, Ohio, and Indiana tends to be about 30 feet, excluding roadway shoulders.

ROW widths range from 240 feet to 360 feet in rural areas. Generally in the rural segments, there are grass-covered slope areas extending 50 feet to 100 feet from the roadway shoulder to the ROW fence on each side. In the urban areas, the side-slope areas are usually steeper, with retaining walls in many locations.

The I-90 route leaves the Buffalo area via Lackawanna and other suburbs before curving southwesterly along the south shore of Lake Erie. The route passes about five miles south of the city of Erie, Pennsylvania. Cleveland is the largest urban area that I-90 passes through between Buffalo and Chicago. I-90 also passes through several Cleveland suburbs as well as passing immediately adjacent to the Cleveland CBD. Along most of the length of I-90 through the Cleveland area, the median consists of paved shoulders and a concrete barrier wall.

West of the Cleveland area, I-90 follows the Ohio Turnpike, a toll road, to the Ohio-Indiana state line. The route passes about seven miles south of the Toledo CBD. In Indiana, I-90 is the Indiana

Toll Road, which passes two and one-half miles north of the Elkhart CBD, and three miles north of the South Bend CBD. I-90 then passes through Gary and Hammond and enters the Chicago area from the south on the Chicago Skyway, a toll road, before joining the Dan Ryan Expressway (I-94). I-90 passes the Chicago CBD (Loop) before continuing west as the Eisenhower Expressway.

The vertical alignment of the existing highway is fairly flat, while the horizontal alignment is characterized by tangent sections with horizontal curves generally one degree or less. Across major lengths of the corridor, particularly across north central and northwest Ohio and northern Indiana, the terrain is quite flat with minimal gradients and curvature. Across northwest Indiana, northeast Ohio, Pennsylvania and western New York State, there are somewhat greater grades. The grades of the highway in the Chicago area are also quite flat, except over the major structures along the Chicago Skyway. Examples of the more severe horizontal curves are in the urban areas of Cleveland, particularly three curves in the vicinity of the CBD of about five to ten degrees. Numerous additional severe horizontal curves are located in the northwest Indiana and Chicago areas.

The existing highway is completely grade-separated from other roads and railroads. In areas of flat terrain, I-90 generally crosses over other roadways, with both overpasses and underpasses in areas of varying elevation, and near cities. Otherwise, potential obstructions are limited to connecting ramps to interchanges, ramps and parking areas at service plazas, and toll plazas, that are usually located at each end of the toll segments.

The alignment crosses several major waterways and associated valleys, including Eighteen Mile Creek west of Buffalo; the Grand River east of Cleveland; the Cuyahoga, Chagrin, and Rocky Rivers near Cleveland; the Vermilion, Huron, and Sandusky Rivers west of Cleveland; the Maumee River near Toledo; and Wolf Lake, the Calumet River, and the Chicago River near Chicago.

Additional data concerning the I-90 Corridor between Buffalo, Cleveland and Chicago are shown in Table 2-11.

Table 2-11. I-90 Corridor from Buffalo to Cleveland and Chicago Additional Data.

Approximate Milepost Locations	Description
(NYS Thruway)	
426	I-90 at I-190 near Buffalo. Three lanes each way. Narrow median with guardrail. Suburban area.
430.5	Toll plaza. West of plaza, two lanes each way. Generally rural area to Ohio MP 188 (Cleveland), except near Erie, Pennsylvania.
432 - 490	Varying median width, approximately 50 feet to more than 150 feet.
494.5	Toll plaza.
496	New York/Pennsylvania State Line.
(Pennsylvania)	
45 - 0	Two lanes each way. Generally uniform median approximately 60 feet wide.
(Ohio)	
244	Two lanes each way. Median approximately 80 to 90 feet wide.
196	Median widens to approximately 150 feet.
188	Interchange with I-271. Wide medians. Third lane each way begins. Median narrows to approximately 40 feet west of interchange. Cleveland and suburban area MP 188 to MP 154.
185	Interchange with SR-2. Restrictive horizontal curves. Four lanes each way west of the interchange. Median narrows to paved area with concrete barrier.
174	Interchange with SR-2. Restrictive horizontal curve of more than 10 degrees.
170	Interchange with I-71. Restrictive horizontal curve of approximately 10 degrees.
168	Wide median with steep embankment.
168 - 164.5	Open median approximately 40 feet in wide.
164.5 - 159	Narrow paved median with concrete barrier.
159-142	Two lanes each way. Median approximately 30 to 50 feet wide. Generally rural area begins at MP 154. Additional open space, about 75 feet each side.

Table 2-11 Continued.

142.6	Toll plaza, entering Ohio Turnpike. Restrictive horizontal curves.
142 - 70	Rural area, few curves. Median about 50 feet. Additional open space 50 to 100 feet.
70 - 50	Suburban Toledo. No restrictions except Maumee River crossing.
50-0	Rural, tangent, very flat.
3	Toll plaza.
(Indiana)	
157	Ohio/Indiana State Line
157 - 137	Rural, moderate curvature. Median about 50 feet, additional open space approximately 75 to 100 feet.
153	Toll plaza.
137 - 84	Generally flat and tangent.
84 - 72	South Bend/Elkhart suburban area.
72 - 26	Rolling terrain, mostly rural, moderate curvature.
26 - 17	Northwest Indiana suburban area. More frequent curvature and crossing structures. Many marshes and wet areas.
17 - 13	Concrete median wall begins and open space narrows each side. Heavy concentration of industry, and railroad and power line ROW.
13 - 9	Marsh area.
9 - 5	Roadway elevated through industrial area. Concrete median with adjacent open space of 50 to 75 feet.
3 - 0	Three lanes each direction. Crossing of Wolf Lake. Toll plaza.
(Illinois)	
8 - 0	Urban industrial area. Large bridge over Calumet River. Toll plaza. Three lanes each way. Very restrictive for high-speed use.
	I-90/I-94 joint use of Dan Ryan Expressway to Chicago CBD (Loop), 8-12 lanes with local transit lines in median. Very restrictive, unsuited for high-speed use.

Technical Feasibility. The extension of New York State high speed surface technology on this corridor appears to be feasible for Maglev, due to available ROW, horizontal curvature, and vertical curvature conditions. Preliminary evaluation of the conditions and costs of operating a VHSR system in the highway right-of-way eliminated this option for New York State. VHSR, for reasons described in Section 2, may be more difficult to implement. The corridor provides access to city centers and intermodal transfer centers in Cleveland and Chicago. Access to the intermediate cities of Erie, Toledo, and South Bend is not direct, but viable suburban station sites are identifiable.

The most significant restrictions exist in the Cleveland and Chicago areas. Restrictions near the Cleveland CBD area can be avoided using existing railroad/transit corridors west of the CBD for about four miles from a crossing of I-90 to the CBD, and east of the CBD for about ten miles. The Tower City Center transit/retail/office development in the CBD is the current planned future intermodal transfer site, and can be accessed by this diversion. This central city location would also connect to the proposed Ohio high-speed rail system to Columbus and Cincinnati.

Approaching Chicago, restrictions on the I-90 route corridor become very severe near the Indiana/Illinois border. However, an existing parallel Conrail/Amtrak railroad corridor seems well suited for high-speed use over the remaining 16 miles to the Chicago CBD. The station site might logically be the Union Station area on the west side of the CBD, where connections to other local and regional transportation including other possible high-speed systems could be made. This includes the proposed Chicago to Detroit high-speed system, that would likely use this same corridor for the final 20- to 25-mile approach to Chicago.

Travel Time Estimate. Average speeds were determined for the New York alignments as previously described. Applying these averages to this extension suggests that Maglev travel times from Buffalo to Chicago could range from four-and-one-half to more than five hours, depending on station stop and alignment details. The flat, largely rural terrain is favorable for extended distances permitting high speeds.

Southern Extension From New York City To Washington

The technical feasibility of extending an HSGT system to other regional destinations was investigated for the Amtrak Northeast Corridor from New York to Washington, DC. About 225 miles, this corridor crosses New Jersey, a corner of Pennsylvania, Delaware, and Maryland before reaching the District of Columbia.

Existing Conditions. This is the only passenger railroad in the United States with characteristics resembling those of a high-speed system. The line has maximum operating speeds of up to 125 mph, allowing travel times of as little as 2 hours and 35 minutes from end to end, which is an average speed of about 77 mph, including stops. In combination with extensions to Boston and Harrisburg, this line carries a majority of Amtrak's passengers.

Significant improvements to this line have been completed since the late 1970s, and are ongoing, by the Northeast Corridor Improvement Project (NECIP). These improvements include grade-crossing elimination, station improvements, a major track realignment, and other track/signal/catenary work. The line is completely electrified, with some portions controlled by Centralized Electrification and Traffic Control (CETC), an advanced system that provides centralized control of signalling and electric-traction power.

The entire route is through highly developed urbanized areas, with stations located generally in the center cities. The ROW is completely fenced and grade-separated. Adjacent non-electrified freight tracks parallel the main line in many locations, leaving little available space on the ROW for new trackage or guideway systems without removing existing trackage.

The Northeast Corridor consists of three operating divisions:

The Baltimore Division, From Washington Union Station through Baltimore to near Wilmington, Delaware, is mostly a three-track line, with usually more than 70 daily Amtrak trains and State of Maryland (MARC) commuter trains between Washington and Baltimore. Numerous freight trains are operated mostly at night. A major restriction in this segment of the corridor is the Baltimore & Potomac Tunnels, just south of Baltimore's Pennsylvania Station. This series of two-track tunnels, completed in 1873, includes eight-degree curves and very limited clearances, and is a major bottleneck in terms of capacity and train speed.

The Philadelphia Division, a four-track section, includes the portion of the Northeast Corridor from Wilmington through Philadelphia to Trenton, New Jersey. More than 80 Amtrak trains operate over this Division, with more between Philadelphia and Trenton. The Southeast Pennsylvania Transportation Authority (SEPTA) operates another 60 or more commuter trains over parts of this corridor. Conrail operates freight trains as well.

The New York Division includes the Northeast Corridor segment from Trenton through Newark, New Jersey, to Pennsylvania Station and beyond to Shell interlocking (in The Bronx). There are four to six tracks from Trenton to a junction west of the Hudson River, where only two tracks pass through the Hudson River tunnels to Pennsylvania Station. More than 80 Amtrak trains and more than 260 New Jersey Transit commuter trains operate west of New York. About half of the NJT trains leave the corridor within 20 miles of New York. Conrail trains use portions of this segment as well, generally west of Newark. The Amtrak West Side Line enters Pennsylvania Station trackage along with the New York Division tracks on the west side of the station. The Hudson River tunnels are an obvious restriction, given the large numbers of trains.

Technical Feasibility. The extension of New York State HSGT technology on this corridor is clearly very desirable due to the large populations in the corridor. The existing railroad is generally compatible with the VHST technology under consideration, so equipment designed for New York State theoretically could operate on the Northeast Corridor. A Maglev system, of course, would require the addition/replacement of trackage with the guideway system.

The existing alignment is restricted largely by horizontal curvature, since it was built before the turn of the century. Considerable study work was undertaken early in the NECIP program, with the intent of increasing train speeds through sharp curves and other restrictions. As summarized in the Federal Railroad Administration's *Northeast Corridor High Speed Rail Passenger Service Improvement Project* in 1975, 31 curves originally were targeted for realignment. Had this been accomplished, more than six additional minutes could have been saved. The cost for this work, over \$80 million (1975), was prohibitive.

The dense urban development of the adjacent areas makes extensive curve realignment very disruptive and costly. For this reason, and a lack of funding, no detailed realignment analysis has been done for speeds approaching 200 mph on this route. Amtrak has begun considering European-designed equipment with tilt capabilities that permit increased speeds without changes in curvature. These tests are in progress in 1993.

Travel Time Estimate. A comparative evaluation of this corridor using data developed for the New York State corridor is imprecise due to the difficulty and expense of realignments in developed areas. However, applying New York State average speeds to this extension suggests that:

- VHSR travel times from New York to Washington could approach two hours; and
- Maglev travel time could be even less, depending on station stops and alignment details.

Eastern Extension from Albany to Boston

This possible extension to the New York State HSGT system would use the Interstate 90 corridor from Boston to Albany, a distance of 166 miles. The highway begins near the Atlantic Ocean in central Boston and runs westward past Worcester and Springfield, Massachusetts to Albany, New York, serving as the major east-west highway corridor in Massachusetts. After crossing the state line from Massachusetts to New York, I-90 meets I-87, the NYS Thruway, near Albany.

Existing Conditions. I-90 passes through several Boston suburbs, passing within two miles of the Framingham CBD and passing approximately four miles south of the Worcester CBD. The corridor passes four miles north of the Springfield CBD, then continues westward, passing ten miles south of Pittsfield, Massachusetts before entering New York. I-90 passes just north of Rensselaer, New York and enters Albany from the east, two miles north of Empire State Plaza. The I-90 continues west to join the Thruway near the SUNY-Albany campus.

In central Boston, the highway is four to five lanes wide in each direction with no shoulder. From the outskirts of Boston to Sturbridge, halfway across Massachusetts, there are three lanes and a full-width shoulder in each direction. From Sturbridge to the New York State line there are two travel lanes and a full shoulder in each direction. The highway's median is generally an open, unpaved space, as wide as 100 feet in rural areas. In metropolitan Boston and near the more urbanized areas around Albany, Springfield, and Worcester, the median is narrow, sometimes no more than paved shoulders and a concrete barrier, a total of eight feet wide.

The average ROW width along I-90 is 300 feet. In urban areas and in areas where topography limits the width, such as rock cuts, the ROW is narrower. ROW widths vary from 150 in some urban areas to more than 400 feet in the mountainous terrain of western Massachusetts.

The I-90 alignment has many curves, traveling though generally hilly terrain in the eastern half of Massachusetts, and through mountainous terrain in the western half of the state. Generally the

vertical alignment is relatively flat, despite the terrain. More severe horizontal curves are located within the Boston metropolitan area, particularly approaching the Boston CBD.

In Massachusetts alone, more than 60 bridges cross over I-90. The highway itself crosses more than 90 other highways, streets, rivers, and railroads. Major bridge structures carrying I-90 over waterways include the Connecticut River at Springfield and the Hudson River at Albany. Toll booth plazas are located on the Massachusetts Turnpike within the Boston metropolitan area (two locations) and at the New York State line.

Additional analyses of potential transportation applications along this corridor are in a report by Vanesse Hangen Brustlin, Inc. for the Massachusetts Bay Transportation Authority, and a current study by EBASCO.

Technical Feasibility. The extension of New York State high-speed surface technology on this corridor appears feasible, because available ROW, horizontal curvature, and vertical curvature conditions seem not unlike portions of the New York State alignment. Additional work is required to comprehensively evaluate conditions on this segment.

Travel Time Estimate. Applying New York State averages to this extension suggests that:

- VHSR travel times from Albany to Boston could be two hours or less, depending on station stop and alignment details; and
- Maglev travel times would be one- to one and one-half hours.

This route's terrain is generally more rugged and mountainous than the New York State segments, which would limit speeds and increase costs.

Section 3
MARKET ANALYSIS

SUMMARY

This section presents ridership and passenger revenue forecasts for alternative HSGT systems that would provide service in the New York City-Albany-Buffalo corridor. For this task, the HSGT systems are assumed to be part of a larger regional network providing service east to Boston, Massachusetts; west to Chicago, Illinois (via Cleveland, Ohio); and south to Washington, D.C. The primary focus of the demand analysis in this study is intercity trip-making within New York State.

Currently in the New York State HSGT corridor, intercity trips can be made by four modes — air, rail, bus, and automobile. Commuter air service is provided between city pairs in the corridor. Amtrak provides daily intercity rail service between New York City (Pennsylvania Station) and Albany-Rensselaer with intermediate stops at Yonkers, Croton-Harmon, Poughkeepsie, Rhinecliff, and Hudson. Amtrak also provides service between Albany and Buffalo with intermediate station stops at Schenectady, Amsterdam, Utica, Rome, Syracuse, and Rochester. The frequency of trains that operate in the corridor varies by day of week and station pair. In general, however, Amtrak operates about twice as many trains between New York City and Albany-Rensselaer as it does between New York City and Buffalo. Metro-North Commuter Railroad offers additional train service between New York City (Grand Central Terminal) and Poughkeepsie.

Intercity bus service approximately parallels the major cities served by Amtrak particularly in the alignment west of Albany, and also serves many smaller areas between Albany and New York City. Given that bus users place a low value on time along with intercity bus volume, bus trips are not

considered in this report. Given the ubiquity of the automobile, there is intercity auto travel between all city pairs.

In developing HSGT ridership and passenger revenue projections, it was necessary to assemble a file of intercity trips by existing modes that were made in the base year. To do this, air origin/destination (O/D) volumes (for "true" O/D trips) were obtained from the 10 percent sample collected by the Federal Aviation Administration. Annual rail (Amtrak) volumes on a station-to-station basis in New York State were obtained from the New York State Department of Transportation, which tabulates this information from Amtrak data. Estimated annual auto O/D volumes were obtained from an intercity travel-demand model developed by the Volpe National Transportation Systems Center (VNTSC) that relates auto travel between city pairs to socioeconomic and other descriptors for each city pair. This approach is necessary because multiple highway paths are possible for some O/D pairs and true auto O/D data are unavailable.

In addition to the base year O/D volume information, it was necessary to specify various HSGT level-of-service characteristics. In this instance, the basecase assumes travel times that have been calculated for an "aggressive" Maglev system (with an average speed of 186.9 mph). Based on guidance for this study, basecase HSGT fares were set at three times conventional rail fares, with business and nonbusiness fares priced equally. This fare was selected because airfares within New York State are very high and comparisons based on rail fares were thought to be a better measure. The basecase also included base assumptions with regard to the cost of automobile operation and passenger station wait times which are a function of frequency of operation. With respect to frequency of operation, service would be provided at half-hour intervals during peak travel periods and at hourly intervals during other times over an 18-hour day.

Following establishment of ridership projections for the basecase, sensitivity analysis was performed to forecast ridership with alternative assumptions on travel time, (with longer travel times associated with less aggressive Maglev alignments and the slower speed VHSR and incremental options), passenger fare, frequency of operation, the cost of automobile operation, as well as terminal wait and access/egress times.

The sensitivity analysis showed that maximum system fare box revenue for the basecase aggressive Maglev alternative was achieved at a fare roughly equivalent to 220% of existing rail. At this point of operation, over 5.2 million trips would be made annually in New York State (only) in 2010, resulting in passenger revenues of \$497 million dollars (in 1992 dollars). For the entire regional

HSGT system, extending west to Chicago, east to Boston, and south to Washington, D.C., we estimate that nearly 20.5 million annual trips would be made in 2010.

The reader should note that alternative fare price structures, such as are common in the airline industry, offering a variety of fares differentiated by such things as time of day, business/non-business, and the number of days between ticket purchase and departure, would produce different ridership volumes. Further increases in system revenue may also be possible with such an alternative fare structure.

The analysis further showed that the fare which produces maximized farebox revenue is slightly different for each of the performance options considered. For the incremental option, maximized revenue is achieved at a fare roughly equivalent to 300% of existing rail (the basecase fare). For this option it is quite likely that a fare structure designed to maximize system revenue would not be determined to be appropriate or in the public interest. Such issues are beyond the scope of this initial comparative evaluation of the technical feasibility, market and revenue potential of the options.

The analysis found that the implementation of "express" train service would result in higher average speeds and an increase in ridership for certain city pairs. Conversely, as average speeds decrease and travel times increase, the demand on diversion and accompanying revenues to HSGT declined. As a consequence, the demand for both VHSR and Incremental rail is less than for Maglev. Incremental rail, however, has a performance close to VHSR unless the alignment is aggressively modified to remove speed-limiting curves. A lack of new ROW availability may prevent the cost effective potential of VHSR technology to be realized. As a result, Incremental rail has the potential to provide a higher return for the initial capital investment than the VHSR scenario, assuming the ROW becomes available and institutional, regulatory and legal issues previously described can be resolved.

Freight revenues estimates were made based on sensitivity to shipping rates. Three categories of expedited freight appear to be the best market opportunity based on interviews with major shippers and transporters of freight. The principal freight markets identified were: Express Surface; Air Cargo; and Less than Truckload (LTL). The freight revenue potential was estimated at \$231 million per year from all modes, assuming existing infrastructure is in place at the stations and terminal locations. Some portions of this market are most sensitive to rates and reliability.

INTRODUCTION

This section presents ridership and passenger revenue forecasts for alternative HSGT systems that would provide service in the New York City–Albany–Buffalo corridor. For this study it is assumed the HSGT systems would be part of a larger regional network providing service east to Boston, Massachusetts; west to Chicago, Illinois (via Cleveland, Ohio); and south to Washington, D.C. The primary focus of the ridership analysis in this study is intercity trip-making in New York State, based on HSGT performance travel times from alignment data in New York State. A qualitative analysis of level-of-service characteristics for extensions outside New York State has been performed, allowing for an assessment of regional HSGT demand.

Between New York City and Albany, the fastest Amtrak trains currently operate at an *average* speed of about 60 mph, including acceleration, deceleration, and dwell time. This average (scheduled) speed increases slightly to 62.1 mph for Amtrak service between Albany and Buffalo (Exchange Street Station). For this study, it is estimated that if the ROW was available an "aggressive" VHSR system could operate at an average speed of 116.1 mph over the entire corridor from New York City to Buffalo including acceleration, deceleration, and station dwell times. It is estimated that an "aggressive" Maglev system with tilt capabilities would operate at an average speed of 186.9 mph over the entire corridor length, assuming a top speed of 300 mph. It is also assumed that an Incremental rail system that utilizes a locomotive currently under development would achieve an average speed of approximately 100 mph from New York City to Buffalo.

EXISTING INTERCITY TRAVEL

Currently in the New York State HSGT corridor, intercity trips can be made by air, rail, bus, and automobile. Air service is provided between many airports. For this study the primary facilities are the three New York City airports, LaGuardia, Newark, and Kennedy; Albany County Airport serving the Albany, Troy, and Schenectady metropolitan areas; Oneida County Airport serving Utica; Syracuse Hancock International Airport; Rochester Monroe County Airport; and the Greater Buffalo International Airport.

Amtrak provides daily intercity rail service between New York City (Pennsylvania Station) and Albany–Rensselaer with intermediate stops at Yonkers, Croton–Harmon, Poughkeepsie, Rhinecliff, and Hudson. Amtrak also provides service between Albany and Buffalo with intermediate station

stops at Schenectady, Amsterdam, Utica, Rome, Syracuse, and Rochester. The frequency of trains that operate in the corridor varies by day of week and station pair. In general Amtrak operates about twice as many trains between New York City and Albany-Rensselaer as it does between New York City and Buffalo. Metro-North Commuter Railroad offers additional train service between New York City (Grand Central Terminal) and Poughkeepsie.

Intercity bus service approximately parallels the major cities served by Amtrak particularly in the alignment west of Albany and also serves many smaller areas in the corridor between Albany and New York City. Given the low value of time exhibited by bus users along with the intercity bus volume, bus trips are not considered in this report. Intercity auto travel is possible between all city pairs via the New York State Thruway, with alternative routes along the southern tier to and from Manhattan.

INTERCITY TRAVEL VOLUMES

To project HSGT ridership and revenue for the alternative alignments and technologies, a file of intercity trips made in one base year using existing modes was necessary. Information on annual intercity modal flows cannot be reliably derived from modal preference surveys which were conducted for this study. Intercity volumes must be obtained elsewhere, including O/D surveys done by others.

Table 3-1 summarizes 1991 *intercity* volumes by air, auto, and rail between selected cities in New York State, and between cities in the larger regional network. Table 3-1 shows intercity volumes on an aggregate basis. Trips data have actually been obtained on a finer city-pair basis.

The air O/D volumes for "true" O/D trips presented in Table 3-1 and elsewhere in this report were derived from the 10 percent sample collected by the Federal Aviation Administration, which is widely perceived as an acceptable data set to obtain true O/D trips made by air for the base year (1991). Over time, however, the earlier data on commuter volumes are suspect due to changing practices in code sharing with major (noncommuter) carriers and reporting procedures.

Annual rail (Amtrak) trips on a station-to-station basis within New York State and for certain corridors outside New York State were obtained from the New York State Department of Transportation, which tabulates this information from Amtrak data. Rail trips for some city pairs

outside New York State were obtained from tabulations prepared for Amtrak (Booz Allen & Hamilton, 1989).

Annual auto O/D volumes were obtained from an intercity travel-demand model developed by the Volpe National Transportation Systems Center (VNTSC) that relates auto travel between city pair to socioeconomic and other descriptors for each city pair. This approach is necessary because multiple highway paths are possible for some O/D pairs, and other data are unavailable.

Table 3-1. Annual Intercity Trips by Mode and Corridor, 1991.

(One-way in Both Directions)

Corridor	Mode		
	Air	Auto	Rail
New York State ⁽¹⁾	1,522,000	22,443,000 ⁽⁵⁾	744,000
Western Extension ⁽²⁾	2,826,000	4,799,000	35,000
Southern Extension ⁽³⁾	3,097,000	18,693,000	2,917,000
Eastern Extension ⁽⁴⁾	4,924,000	9,164,000	638,000

⁽¹⁾ Includes only major city pairs identified in Section 2, that have an origin and destination in New York State. If through rail trips on Amtrak and intermediate stations not included in the HSGT system were included, this number would be higher. These through trips are included in the extensions.

⁽²⁾ "Western Extension" includes only intercity trips for the following city pairs: Albany and Cleveland, Albany and Chicago, Buffalo and Cleveland, Buffalo and Chicago, New York City and Cleveland, and New York City and Chicago.

⁽³⁾ "Southern Extension" includes only intercity trips between Albany and Philadelphia, Albany and Washington, Buffalo and Philadelphia, Buffalo and Washington, New York City and Philadelphia, and New York City and Washington.

⁽⁴⁾ "Eastern Extension" includes only intercity trips between Boston and Albany, Boston and Buffalo, Boston and New York City, Boston and Cleveland, Boston and Chicago, Boston and Philadelphia, and Boston and Washington.

⁽⁵⁾ Represents auto trips more than 85 miles long in the HSGT corridor.

SOURCE: See text.

MODELING RESULTS

Total Travel-Demand Models

To project intercity trip making for 2010 by current modes, and to develop a means to quantify induced demand, a variety of time-series models were estimated following Step 1 of the approach described in Appendix 3. The total travel-demand models for air, rail, and auto modes are described in the following sections.

Air. Figure 3-1 shows annual air trips made between New York City and Buffalo from 1979 to 1990. Using information on average annual air fares converted to real dollars using the consumer price index for New York-Northern New Jersey-Long Island area, air frequencies, air travel times, and O/D population, a time-series model was estimated from 1979 to 1990. The results of the air business and air nonbusiness mode-preference models described in this chapter were used to convert the air level-of-service (LOS) terms to the generalized price of air travel. The final air total-travel model (dropping the y for year) can be written as:

$$T_{O,D,air} = (P_O + P_D)^{+1.015} \times (G.P.)^{-1.664} \quad (3-1)$$

(26.7) (-5.4) (t-statistics)

where:

- $T_{O,D,air}$ = Annual air trips between origin (O) and destination (D)
- P_O = Annual population for origin, O
- P_D = Annual population for destination, D
- G.P. = Generalized price of travel between O and D by air

This model had an R^2 of 0.75. The signs on the coefficients for the population and generalized price terms are correct, and all variables are statistically significant. Since this is a log-log model, the coefficients can be interpreted as elasticities. For example, holding air LOS constant, the model indicates that a one percent increase in population will result in a 1.015 percent increase in air travel.

SOURCE: FAA 10 percent sample with calculations by Charles River Associates, 1993.

Figure 3-1. Annual Air Trips between New York City and Buffalo (1979 to 1990).

By dividing Equation 3-1 by itself and rearranging terms, the model can project future air travel between any O/D pair as follows:

$$T_{2010,air} = T_{1991,air} \times \left[\frac{(P_O + P_D)_{2010}}{(P_O + P_D)_{1991}} \right]^{+1.015} \times \left[\frac{G.P._{2010}}{G.P._{1991}} \right]^{-1.664} \quad (3-2)$$

Rail. Figure 3-2 shows annual rail trips made between New York City and Albany-Rensselaer from 1984 to 1990. Using information on average annual rail fares converted to real dollars using the consumer price index for the New York-Northern New Jersey-Long Island area, rail frequencies, rail travel times, and O/D population, a time-series model for 1984 to 1990 was projected. Since neither rail nor air LOS was statistically significant in the rail model, the final rail total-travel model (dropping the y for year) can be written as:

$$T_{O,D,rail} = (P_O + P_D)^{+0.898} \quad (3-3)$$

(9.9) (t-statistic)

where

- $T_{O,D,rail}$ = Annual rail trips between origin (O) and destination (D)
- P_O = Annual population for origin O
- P_D = Annual population for destination D

This model, although exhibiting a statistically significant coefficient of the correct sign and a very sensible value, had an R^2 of only 0.20. Including a cross-elasticity term such as real air fare did not improve the model. Given the relatively small share of existing rail trips in the HSGT corridor, the model is acceptable. Again, dividing Equation 3-3 by itself and rearranging terms, the model can project future rail travel between any O/D pair as follows:

$$T_{2010,rail} = T_{1991,rail} \times \left[\frac{(P_O + P_D)_{2010}}{(P_O + P_D)_{1991}} \right]^{+0.898} \quad (3-4)$$

SOURCE: New York State Department of Transportation.

Figure 3-2. Annual Rail Trips between New York City and Albany-Rensselaer (1984 to 1990).

Auto. Time series information about auto travel on an O/D basis in New York State is unavailable. Such a model, however, has estimated travel between Houston and Dallas from 1979 to 1989 (CRA, 1991).

Expressed in the same format as the previous air and rail total travel models, this model can be written as:

$$T_{O,D,auto} = 0.449(P_O + P_D)^{1.0} \times (PCI)^{+0.607} \quad (3-5)$$

(16.6) (3.0) (t-statistics)

where:

$$T_{O,D,auto} = \text{Annual auto trips between origin (O) and destination (D)}$$
$$P_O = \text{Annual population for origin, O}$$
$$P_D = \text{Annual population for destination, D}$$
$$PCI = \text{Weighted per capita real income for O and D}$$

This particularly attractive model indicates that intercity auto travel between two city pairs is exactly proportional to population when controlling for real per capita income. The population sum term is highly significant with a t-statistic of 16.6. The overall model has a corrected R^2 of 0.98. Dividing Equation 3-5 by itself and rearranging terms, the model can project future auto travel between any O/D pair as follows:

$$T_{2010,auto} = T_{1991,auto} \times \left[\frac{(P_O + P_D)_{2010}}{(P_O + P_D)_{1991}} \right]^{+1.0} \times \left[\frac{PCI_{2010}}{PCI_{1991}} \right]^{+0.607} \quad (3-6)$$

Mode-Diversion Models

This section presents the various mode-diversion models estimated for each market segment based on the survey data collection previously discussed. These diversion models are described in general terms in Step 2, Appendix 3.

Table 3-2 shows the coefficients and *t*-statistics for six mode-choice models using data from surveys conducted in New York. All the coefficients are statistically significant except for the HSGT constants in the air and conventional rail nonbusiness models. The HSGT constant in these models, therefore, cannot be shown statistically to be significantly different from zero. A value of exactly zero for the mode-specific constants would imply that, if all times and costs of the two modes were equal, nonbusiness air and rail travelers would be indifferent when choosing between their current mode and HSR; i.e., 50 percent would choose one mode, and 50 percent would choose the other. Given that three of these modes are common carrier modes, this finding is not unexpected. A negative (positive) value of the HSGT constant implies that the share of current travelers who would prefer HSGT is less (more) than 50 percent.

**Table 3-2. Estimated Mode-Choice Model Coefficients by Market Segment
For Intercity Travel in New York State.**

Variable	Market Segment					
	Air		Auto		Rail	
	Business	Nonbusiness	Business	Nonbusiness	Business	Nonbusiness
Cost [1992 dollars]	-0.0375 (-3.7)	-0.1950 (-6.2)	-0.0054 (-1.7)	-0.0105 (-2.1)	-0.0178 (-2.5)	-0.0818 (-15.3)
Time [Hours]						
Line-haul	-2.05 (-8.3)	-3.923 (-5.2)	-0.214 (-1.7)	-0.157 (-2.1)	-0.850 (-11.3)	-1.146 (-17.5)
Access/Egress	-1.37 (-8.3)	-3.923 (-5.2)	-0.143 (-1.7)	-0.105 (-2.1)	-0.283 (-11.3)	-0.382 (-17.5)
Wait	-2.05 (-8.3)	-1.962 (-5.2)	-0.107 (-1.7)	-0.079 (-2.1)	-0.283 (-11.3)	-0.382 (-17.5)
Wait x Acc/Egr ÷ Line Haul	—	—	—	-0.1866 (-2.2)	—	—
HSGT Constant	0.8590 (4.9)	0.6509 (1.4)	-0.2789 (-1.9)	-0.6364 (-2.9)	0.3806 (4.6)	0.0633 (1.0)

Note: (t-statistics in parentheses)

SOURCE: Charles River Associates, 1993.

Cost and travel-time coefficients of all models presented in Table 3-2 are correctly negative, implying that increases in the travel time or cost of a mode will reduce its use.

Based on estimated mode-diversion models in Table 3-2, it is possible to compute how intercity air, rail, and auto travelers in New York State value travel time. Table 3-3 illustrates how the implied values of time for individuals traveling in New York varies by trip purpose and current mode. As expected, the values of time for air travelers are higher than for either rail or auto travelers. Also, as expected, the values of time for nonbusiness travelers are much lower than for business travelers. In studies of urban fixed-route and schedule (common carrier) transit travel competing with auto, the value of time for access and wait time is commonly reported to be much greater than the value of time for line-haul

Table 3-3. Implied Values of Travel Time by Mode and Trip Purpose in New York State.
(Dollars per hour in 1992 dollars).

Current Mode	Trip Purpose			
	Business		Nonbusiness	
	Line-Haul Time	Access/Egress Time	Line-Haul Time	Access/Egress Time
Air	\$54.67	\$36.44	\$20.12	\$20.12
Rail	\$47.77	\$15.92	\$14.00	\$ 4.67
Auto	\$40.00	\$26.67	\$15.00	\$10.00

SOURCE: Charles River Associates, 1993.

transit. This result does not appear to be transferable to intercity travel because there are two competing common carriers modes, in addition to a scale difference in the length of the intercity trip. Travelers are willing to pay for the high line-haul speed of air travel, or their companies pay for business travel, to maximize the value of their time to the company and its clients.

For intercity auto travel, models based on Florida data indicate that as trip distance and line-haul time increase auto business and nonbusiness travelers place less importance on access and wait time, and more importance on line-haul time (CRA, 1990). As trip lengths increased to nearly 200 miles, the value of HSGT line-haul time became greater than the value of access/egress and wait time.

The following sections describe how time, direct elasticities, and modal constants vary by six main market segments: air business, air nonbusiness, rail business, rail nonbusiness, auto business, and auto nonbusiness travelers.

Air Business. Air business travelers are predictably sensitive to line-haul travel time. The value of time for business air trips is about \$55 per hour. This figure is 1.4 times the average hourly wage rate of the intercity travelers surveyed in New York, a result that falls in the range reported in a recent Federal Aviation Administration (FAA) comprehensive literature review of air travel-demand models (FAA, 1989). The FAA range of 1.0 to 1.5 times the average wage rate is based on 17 models of air business travel demand.

The value of access/egress time for air business travelers in Table 3-3 is \$36 per hour, which also reflects the premium this segment places on time. Adjusted for inflation this value is still higher than the mid-1980s value of \$17 per hour reported by the FAA, based on airport access data from San Francisco. It is higher than the 1989 value of \$16 per hour for this market segment in Florida; however, traveler incomes in this segment are also higher in New York compared to Florida. However, the latter two values represent the value of airport access time in models of access-mode choice, not intercity mode choice. The latter is expected to produce higher time values.

In logit mode-choice models such as these, direct elasticities are not constant, but vary with the values of the independent variables, and the resulting mode share. Consequently, they depend on the assumed fare and service characteristics and the O/D pair. For example, as shown in Table 3-4, the air business HSGT line-haul time elasticity for travel between the areas served by the HSGT system is about -0.53, while the HSGT fare elasticity is -0.8. The latter value indicates that for this air business-market segment only, the HSGT revenue-maximizing fare is slightly more than the fare for the proposed HSGT service in this corridor.

Finally, the HSGT access/egress time elasticity for air business travelers was -0.16, a much lower value than for the air business line-haul time elasticity of -0.53, indicating the limited importance of access/egress time for common carrier modes.

Table 3-4. High-Speed Rail Elasticities by Mode and Trip Purpose in New York State.

Mode and Trip Purpose	Level of Service Component		
	Line-Haul Time	Access/Egress Time	Fare
Air:			
Business	-0.53	-0.16	-0.84
Nonbusiness	-0.83	-0.49	-1.45
Rail:			
Business	-0.21	-0.08	-0.48
Nonbusiness	-1.02	-0.38	-7.79
Auto:			
Business	-0.15	-0.10	-0.40
Nonbusiness	-0.02	-0.21	-0.96

SOURCE: Charles River Associates, 1993.

The implied values of the HSGT constants shown in Table 3-5 indicate that business air and conventional rail users prefer HSGT. Auto is highly valued compared to HSGT by business and nonbusiness travelers if travel times and cost factors are equal. The travel times and costs of HSGT and auto, however, are not equal between any two O/D pairs in New York. The HSGT constants in the auto mode-choice models mean that the flexibility and privacy of auto are valued very highly relative to HSGT or any common carrier mode.

The values of the HSGT constants in Table 3-5 for air and conventional rail nonbusiness travelers are similar to HSGT in the net effect of the unobserved or unmeasured attributes for each ridership mode. That is, controlling for all the conventional LOS attributes included in the mode-choice model, cost, line-haul time, access/egress time, and wait time, *nonbusiness* travelers perceive air, conventional rail, and HSGT "fixed route and schedule" and common carrier modes as essentially equal.

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**Table 3-5. Implied Value of HSGT Constants by Market Segment in New York State.
(1992 Dollars)**

Current Mode	Trip Purpose	
	Business	Nonbusiness Time
Air	(\$22.91)	(\$ 3.34)
Rail	(\$21.38)	(\$ 0.77)
Auto	\$52.11	\$60.61

Note: Values are equivalent to the fare advantage of the existing mode compared to HSGT keeping all times and costs equal for the competing modes.

SOURCE: Charles River Associates, 1993.

Air Nonbusiness. The relatively few individuals who make local air trips in New York State for nonbusiness purposes are less sensitive than business travelers to line-haul time compared to cost. Line-haul time is estimated at \$20 per hour (Table 3-3), which is about 25 percent less than the \$28 per hour value observed in Texas (CRA, 1991). Since most nonbusiness air travelers pay for their air trips, they clearly value the time savings of the high-speed mode.

The value of access/egress time for air nonbusiness trips is about \$20 per hour, as shown in Table 3-3. This figure is higher than the mid-1980s value of \$10 per hour reported by the FAA for nonbusiness airport access travel to San Francisco's airport, and by a CRA study of Las Vegas nonbusiness airport access travel. However, the higher values of access and wait times for this market segment reflect inflation and the different (intercity) marketplace where the travel choice is made.

The HSGT constant is statistically significant, and its implied magnitude, equivalent to \$3.34, suggests that nonbusiness air travelers are somewhat less likely to use HSGT than air business travelers. The constant represents how much lower than HSGT the air fare would have to be to make travelers indifferent when choosing between air and HSGT.

Auto Business. Travel time is less important for individuals traveling on business by automobile than by air or rail. As previously discussed, individuals who fly would be expected to place a high value on their travel time, while individuals who use auto place lower values on time but place a much higher value on flexibility, privacy, and the ability to make multiple stops. As shown in Table 3-3, the value of line-haul time for relatively high-income auto travelers making intercity business

trips in the New York HSGT corridor, is \$40 per hour. There are no comprehensive studies of the value of intercity auto business travel time. However, this value falls logically between the time values given in the literature for air travelers referred to above and auto nonbusiness travelers. The value of access/egress time of about \$27 for auto business travelers is less than the value of line-haul time for this market segment.

The values of time in Table 3-3 and the demand elasticities for HSGT time in Table 3-4 are consistent across market segments and modes. That is, since auto time is not as valuable as air-travel time, the demand elasticities are lower for auto compared to air. An hour of saved line-haul time on HSGT does not divert as many travelers from auto as from air.

The HSGT constant in the auto business model is worth \$52 of fare reduction to make a traveler indifferent when choosing between auto and HSGT if times and costs included in the model are equal. Thus, intercity travelers who already have selected a common carrier mode (say, air) over auto, are much more likely to switch to another common carrier mode, such as HSGT. Auto business travelers are, therefore, much less likely to switch to HSGT than air or conventional rail business travelers.

Auto Nonbusiness. As shown in Table 3-3, the value of line-haul time for auto nonbusiness trips was nearly the same as for conventional rail, reflecting the discretionary nature of nonbusiness trips relative to business trips. The value of \$15 per hour equals about one-half the average wage rate of auto nonbusiness travelers in New York. This ratio is consistent with the results of a similar HSR study in Texas (CRA, 1991).

The value of access/egress time is less than line-haul time. In the intercity Florida corridors (CRA, 1990), where trip lengths varied greatly, auto nonbusiness access times were valued more than any other market segment for short intercity trips (85 miles). This result is predictable since these travelers, often with children and extra luggage, do not want to divert from auto for short trips on a common carrier mode involving additional access/egress times.

The elasticities for auto nonbusiness travelers in Table 3-4 are similar to those for auto business travelers. The lower time values result in lower time and fare elasticities.

The auto nonbusiness market segment has the largest negative mode-specific HSGT constant (equivalent to \$60.61 among the six travel market segments reported). This result is predictable

since nonbusiness travelers such as individuals on vacation need the features of an automobile most. Therefore, if times and costs are equal, this group of intercity travelers is least likely to switch to HSGT.

Rail Business. The value of line-haul time for rail business travelers, about \$48 per hour, falls about midway between the values of time shown in Table 3-3 for business air and auto travelers in New York. As with these other two market segments, access/egress time values for rail business travelers are less than for line-haul time. A similar finding can be obtained by examining the travel-time elasticities shown in Table 3-4.

The HSGT constant is statistically significant as shown in Table 3-2, and its implied value, equivalent to about \$21 on average, suggests that rail *business* travelers prefer using a higher speed HSGT.

Rail Nonbusiness. The value of line-haul time for nonbusiness rail travelers, about \$14 per hour, is lower than all values of line-haul time for *business* travelers (as expected) and lower than the time values for air and auto business travelers. The value of access/egress time is also low for this market segment, about \$5 per hour as shown in Table 3-3.

The HSGT constant cannot be shown to be statistically different than zero. As indicated in Table 3-2, the t-statistic is 1.0. Consequently, the implied value of the HSGT constant is quite small for this market segment, suggesting that this group of travelers is influenced mainly by level-of-service.

Induced Demand

Induced demand is defined as new trips generated by the presence of the new HSGT system. These trips are made in addition to trips diverted from other modes or other destinations. Induced demand does not include trips taken due to normal population/employment growth. These latter trips are included in the 2010 forecasts made with the total travel-demand models previously described. Induced demand, therefore, essentially reflects a reduction in the "price" of travel.

Due to the relationship between induced demand and modal preference, the methodology for forecasting induced demand must be consistent with the models used to forecast mode diversion. This was done by calculating the change in the generalized price of travel resulting from introducing the HSGT mode and using Equation 3-1 to determine the increase in the number of trips made. Since it is the HSGT mode that causes induced tripmaking, all the additional trips are assumed to be

made that system. If the introduction of a new mode (HSGT, in this instance) does not result in a decrease in the generalized price of travel, this approach will yield no induced trips.

FORECAST OF HSGT RIDERSHIP AND REVENUE

In this report, the "basecase" is the "aggressive" Maglev travel time. Travel times for other HSGT technologies are longer; therefore, projections of HSGT ridership for these alternatives are less than those for the "aggressive" Maglev option.

Base-Year Estimates

Ridership and passenger-revenue projections for HSGT used the annual 1991 base-year modal volumes on an O/D basis. Figure 3-3 shows the percentage of long-distance intercity person-trips made entirely in New York State by mode in 1991. A summary of intercity volumes for all O/Ds by mode and corridor extension, that is, outside New York appears in Table 3-1.

Within New York State it was possible to use the results from air, rail, and auto-user surveys to estimate the share of trips made for each trip-purpose category. These results are summarized in Table 3-6.

SOURCE: Charles River Associates, 1993.

**Figure 3-3. Market Shares of Intercity Trips by Mode (1991)
Along the Buffalo-Rochester-Syracuse-Albany-New York City Corridor.**

For intercity auto travel, trips were disaggregated dividing survey results into three groups: the need for the automobile at the destination; the need to make stops along the way; and all other (long-distance) intercity auto travel. Figure 3-4 highlights the shares of long-distance intercity person trips using this information. Based on an initial estimate from auto survey responses, an average group size of 1.7 and 2.4 was calculated for business and nonbusiness trips, respectively.

Table 3-6. Share of Business/Nonbusiness Person - Trips by Mode in New York State.

	% Business	% Nonbusiness	Total
Air	71	29	100%
Rail	36	64	100%
Auto (All Types)	18	82	100%
Auto (Noncaptve)	13	87	100%

SOURCE: Charles River Associates, 1993.

LOS information pertaining to fares, frequencies, access/egress times, and terminal- processing times for each relevant O/D pair, was used to project the number of trips that could be diverted to HSGT by mode and trip purpose along with induced-demand trips. Table 3-7 summarizes the results for the 1991 base year for trips in the New York State corridor using as input the "aggressive" Maglev travel times previously described.

Table 3-7 shows the passenger trips forecasted with aggressive Maglev performance (TPC-6) with fare adjusted for maximum revenue roughly equivalent to 220% existing rail. The preliminary forecast for the aggressive Maglev system is that it could attract about 4.8 million trips (in 1991, the base year) within the New York State corridor, resulting in gross passenger revenues of \$461 million. This Maglev system would capture more than 84 percent of the existing local air travel in New York State and almost 48 percent of current intercity rail users. Conversely, only about nine percent of long-distance intercity auto travelers within the corridor would divert to the Maglev system. Induced demand represents about 18 percent of the total number of trips diverted for HSGT. For comparison, other estimates of induced demand range from a low of seven percent to a high of 48 percent (TRB, 1991, p. 105). Figure 3-5 graphically shows the ridership results by mode.

SOURCE: Charles River Associates, 1993.

Figure 3-4. New York Corridor: Classification of Intercity Trips.

SOURCE: Charles River Associates, 1993.

Figure 3-5. New York Corridor: Trips by Mode with HSGT (1991).

Summary of Intercity Trips in New York State by Mode and Trip Purpose with and without HSGT (1991)

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Scenario: HSGT Alignment TPC-6, induced demand method=4, HSGT Fare = 220% of rail fare, HSGT wait = 0.25/0.50 hrs

Mode	Total Trips Before HSGT	Total Trips After HSGT	% Diversion to HSGT	HSGT Trips from diversion	HSGT Trips from induced	Total	HSGT Revenue (\$1991) ¹ from diversion	HSGT Revenue (\$1991) ¹ from induced	Total	Mode Share After HSGT
BUSINESS										
Air (Local)	1,088,425	96,561	91.1%	989,864	NA	989,864	\$119,600,651	NA	\$119,600,651	0.3%
Auto	461,584	348,843	24.4%	112,741	NA	112,741	\$8,742,010	NA	\$8,742,010	1.0%
Auto, car at destination	2,809,943	2,155,470	17.4%	454,473	NA	454,473	\$35,507,029	NA	\$35,507,029	6.2%
Auto, en route	2,627,038	2,627,038	0.0%	0	NA	0	\$0	NA	\$0	7.5%
Rail	283,757	51,952	81.7%	231,805	NA	231,805	\$20,110,931	NA	\$20,110,931	0.1%
HSGT	0	1,788,883	NA	NA	NA	NA	NA	NA	\$0	5.1%
Total	7,068,748	7,068,748	25.3%	1,788,883	NA	1,788,883	\$183,960,621	NA	\$183,960,621	20.2%
NONBUSINESS										
Air (Local)	435,561	136,066	68.8%	299,495	NA	299,495	\$34,773,038	NA	\$34,773,038	0.4%
Auto	6,137,748	5,357,897	12.7%	779,849	NA	779,849	\$61,327,047	NA	\$61,327,047	15.3%
Auto, car at destination	13,783,922	12,920,354	6.3%	863,568	NA	863,568	\$67,748,177	NA	\$67,748,177	36.9%
Auto, en route	6,085,731	6,085,731	0.0%	0	NA	0	\$0	NA	\$0	17.4%
Rail	490,314	351,642	28.3%	138,672	NA	138,672	\$13,152,823	NA	\$13,152,823	1.0%
HSGT	0	2,081,584	NA	NA	NA	NA	NA	NA	\$0	5.9%
Total	26,933,275	26,933,275	7.7%	2,081,584	NA	2,081,584	\$176,999,085	NA	\$176,999,085	77.0%
TOTAL										
Air (Local)	1,521,986	232,627	84.7%	1,289,359	NA	1,289,359	\$154,373,689	NA	\$154,373,689	0.7%
Auto	6,599,330	5,706,740	13.5%	892,590	NA	892,590	\$70,069,057	NA	\$70,069,057	16.3%
Auto, car at destination	16,393,864	15,075,823	8.0%	1,318,041	NA	1,318,041	\$103,253,205	NA	\$103,253,205	43.1%
Auto, en route	8,712,770	8,712,770	0.0%	0	NA	0	\$0	NA	\$0	24.9%
Rail	774,071	403,595	47.9%	370,476	NA	370,476	\$33,263,754	NA	\$33,263,754	1.2%
HSGT	0	4,857,399	NA	NA	NA	NA	NA	NA	NA	13.9%
Total	34,002,021	34,988,954	11.4%	3,870,467	886,932	4,857,399	\$360,959,705	\$100,798,455	\$461,758,160	100.0%

¹ Calculated based on the assumptions below.

ASSUMPTIONS

	Business	Nonbusiness
HSGT Fare as % of rail fare	220.00%	220.00%
Stop along the way	46.10%	23.40%
Need car at destination	45.80%	53.00%
Car for line-haul only	8.10%	23.60%

Notes to Assumptions Table.

1. Information on % auto users needing cars at the destination and stopping along the way are based on New York surveys.

2. Auto cost assumptions based on 20 cents/10 cents per mile for business/nonbusiness travelers.

3. Auto occupancy is 1.7/2.4 for business/nonbusiness trips.

Table 3-7. Summary of Intercity Trips in New York State by Mode and Trip Purpose With and Without HSGT (1991).

Market Analysis

Intercity trips that would be made on a Maglev system serving the larger regional HSGT network in the base year have been projected. Since detailed LOS factors have not been developed for these extensions, the estimated diversions to Maglev have been made by analogy, based on the preliminary results for travel in the New York State corridor. Combined results are given in Table 3-8.

Given that with the three extensions shown in Table 3-8, a certain number of HSGT trips will pass through New York State, or have an origin and/or a destination within New York State — but not both, Table 3-9 estimates of passenger-miles that would be made within and outside the State. Clearly for the New York State HSGT corridor from New York City to Buffalo, all passenger-miles are made in the State. For the extensions, only a portion of an HSGT trip would be made in New York State. Passenger-miles for these were determined using O/D HSGT volumes and trip distances, inside and outside New York State.

Future Year Estimates

In addition to the previous 1991 base-year ridership and passenger-revenue projections were made for 2010. The methodology, although nearly identical to the 1991 HSGT projections, can be summarized as follows. The 1991 base-year intercity O/D volumes by air, rail, and auto were first expanded to 2010 using the total travel models shown as Equations 3-2, 3-4, and 3-6, respectively. Since all three equations contain population measures for both the O/D areas, population projections by county were obtained from the New York State Department of Economic Development (NYSDDED, 1991). The population projections prepared by NYSDDED show a slight increase in New York State population of only 0.22 percent per year. The population for counties in the HSGT corridor is expected to increase at a slightly higher rate compared to the state. Consequently, intercity air, auto, and rail trips in New York State are projected to increase at an annual rate of 0.4, 0.3, and 0.6 percent, respectively.

The six modal diversion models shown in Table 3-2 were used to determine the share of trips expected to be diverted to HSGT. Induced demand was calculated as previously described.

Table 3-8. Base Year Annual Maglev Ridership Forecast, 1991.

Corridor	Annual Maglev Ridership⁽¹⁾⁽²⁾
Within New York State	4,800,000
Western Extension	2,400,000
Southern Extension	6,600,000
Eastern Extension	6,200,000
Total	20,000,000

(1) See footnotes to Table 3-1.

(2) Ridership at 220% existing rail fare extrapolated from basecase analysis.

SOURCE: Charles River Associates, 1993.

Table 3-9. Annual Maglev Passenger-Mile Estimates by Location, 1991.

Corridor	Total HSGT Ridership	Passenger-Miles		
		Inside NY State	Outside NY State	Total
New York State	4,800,000	1,057,000,000	0	1,057,000,000
Western Extension	2,400,000	850,000,000	1,065,000,000	1,915,000,000
Southern Extension	6,600,000	228,000,000	1,050,000,000	1,278,000,000
Eastern Extension	6,200,000	998,000,000	1,558,000,000	2,556,000,000
Total	20,000,000	3,133,000,000	3,673,000,000	6,806,000,000

SOURCE: Charles River Associates, 1993.

Table 3-10 projects Maglev demand for 2010. In the HSGT corridor, ridership is projected to increase to 5.2 million trips annually, while passenger revenue increases to \$497 million.

Summary of Intercity Trips in New York State by Mode and Trip Purpose with and without HSGT (2010)

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 Scenario: HSGT Alignment TFC-6, Induced demand method=4, HSGT Fare = 220% of rail fare, HSGT wait = 0.25/0.50 hrs
 NOTE: Assumes 1991 level of service characteristics for all modes.

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Mode	Total Trips Before HSGT	Total Trips After HSGT	% Diversion to HSGT	from diversion	HSGT Trips from induced	Total	HSGT Revenue (\$1991) ¹			Mode Share After HSGT
							from diversion	from induced	Total	
BUSINESS										
Air (Local)	1,176,374	104,912	91.1%	1,071,462	NA	1,071,462	\$129,571,049	NA	\$129,571,049	0.3%
Auto	483,785	364,394	24.7%	119,391	NA	119,391	\$9,314,005	NA	\$9,314,005	1.0%
Auto, car at destination	2,735,478	2,254,121	17.6%	481,357	NA	481,357	\$37,836,364	NA	\$37,836,364	6.1%
Auto, en route	2,753,396	2,753,396	0.0%	0	NA	0	\$0	NA	\$0	7.5%
Rail	307,546	56,362	81.7%	251,184	NA	251,184	\$21,792,662	NA	\$21,792,662	0.2%
HSGT	0	1,923,395	NA	NA	NA	NA	NA	NA	\$0	5.2%
Total	7,456,579	7,456,579	25.8%	1,923,395	NA	1,923,395	\$198,514,080	NA	\$198,514,080	20.2%
NONBUSINESS										
Air (Local)	473,078	147,844	68.7%	325,234	NA	325,234	\$37,779,349	NA	\$37,779,349	0.4%
Auto	6,449,712	5,623,595	12.8%	826,117	NA	826,117	\$65,356,349	NA	\$65,356,349	16.3%
Auto, car at destination	14,484,523	13,569,839	6.3%	914,684	NA	914,684	\$72,187,559	NA	\$72,187,559	36.8%
Auto, en route	6,395,054	6,395,054	0.0%	0	NA	0	\$0	NA	\$0	17.4%
Rail	531,316	381,232	28.2%	150,084	NA	150,084	\$14,248,502	NA	\$14,248,502	1.0%
HSGT	0	2,216,119	NA	NA	NA	NA	NA	NA	\$0	6.0%
Total	28,333,683	28,333,683	7.8%	2,216,119	NA	2,216,119	\$189,571,759	NA	\$189,571,759	76.9%
TOTAL										
Air (Local)	1,649,452	252,756	84.7%	1,396,696	NA	1,396,696	\$167,350,399	NA	\$167,350,399	0.7%
Auto	6,933,498	5,987,989	13.6%	945,508	NA	945,508	\$74,670,354	NA	\$74,670,354	16.2%
Auto, car at destination	17,220,001	15,823,960	8.1%	1,396,042	NA	1,396,042	\$110,023,923	NA	\$110,023,923	42.9%
Auto, en route	9,148,450	9,148,450	0.0%	0	NA	0	\$0	NA	\$0	24.6%
Rail	838,862	437,594	47.8%	401,268	NA	401,268	\$36,041,164	NA	\$36,041,164	1.2%
HSGT	0	5,203,651	NA	NA	NA	NA	NA	NA	NA	14.1%
Total	35,790,262	36,854,400	11.6%	4,139,514	1,064,137	5,203,651	\$388,085,840	\$108,943,021	\$497,028,861	100.0%

¹ Calculated based on the assumptions below.

ASSUMPTIONS

	Business	Nonbusiness
HSGT Fare as % of rail fare	220.00%	220.00%
Stop along the way	46.10%	23.40%
Need car at destination	45.80%	53.00%
Car for line-haul only	8.10%	23.60%

Notes to Assumptions Table:

- Information on % auto users needing cars at the destination and stopping along the way are based on New York surveys
- Auto cost assumptions based on 20 cents/10cents per mile for business/nonbusiness travelers
- Auto occupancy is 1.7/2.4 for business/nonbusiness trips

Table 3-10. Summary of Intercity Trips in New York State by Mode and Trip Purpose With and Without HSGT (2010).

Market Analysis

Ridership Projections by Technology

Based on the same frequency and fare assumptions used for the Maglev projections previously presented, but modifying travel times to be consistent with the three technologies examined, Table 3-11 shows annual HSGT ridership projections for the New York State portion only in 2010. Annual HSGT passenger revenues expressed in 1992 dollars are also shown. For the ridership estimates presented, Table 3-12 shows the modal diversions and induced-demand levels for the three technologies. To the intercity traveler, the principal difference between the technologies is speed, since no other changes are assumed in fares, frequencies, or other level-of-service factors. While modal diversion and induced-demand increase as travel times improve, Table 3-12 clarifies that the largest increases occur in diversions as travel times are reduced.

**Table 3-11. Annual Ridership and Passenger Revenue-Projections
for Alternative HSGT Technologies.
(At the point of maximum revenue)**

Technology	2010 Annual Ridership	2010 Passenger Revenue (1992 Dollars)
Tilt HSR	3,519,520	\$297,654,070
VHSR	3,923,054	\$343,163,715
Maglev	5,203,000	\$497,000,000

SOURCE: Charles River Associates, 1993.

The values in Table 3-11 reflect the ridership at the point of maximum revenue for reference. This value is approximately 36 percent higher ridership than estimated for the basecase conditions assuming fares equal to three times airfare for the Maglev travel times. Historically however, the fare structure on public transportation systems is not established at the point of maximum revenue. Many factors must be weighed to determine the fares to be charged on a HSGT system in New York.

**Table 3-12. Modal Diversions and Induced Demand
for Three HSGT Alternatives Compared (2010).**

	Induced Trips on <u>HSR/MAGLEV/Incremental</u>	Diverted Trips from Other Modes <u>HSR/MAGLEV/Incremental</u>
Business Travelers		
HSR Baseline	—	1,029,568
HSR Aggressive	—	1,303,632
Maglev Aggressive	—	1,639,084
Incremental Option	—	1,136,771
Non-Business Travelers		
HSR Baseline	—	1,298,623
HSR Aggressive	—	1,408,705
Maglev Aggressive	—	1,600,033
Incremental Option	—	1,338,011
Total		
HSR Baseline	109,790	2,328,191
HSR Aggressive	227,493	2,712,338
Maglev Aggressive	596,225	3,239,117
Incremental Option	145,176	2,474,782

Source: Ridership Estimates, Charles River Associates

Sensitivity Analyses

To determine how ridership and passenger-revenue projections for the option in the base year may vary given alternative (input) assumptions, a series of sensitivity analyses were done for six factors that influence HSGT demand, as shown in Table 3-13. For the basecase there is no change in ridership or passenger revenue. If HSGT fares are reduced to existing rail levels, HSGT ridership more than doubles; that is, it increases by 108.8 percent. However, in this example, passenger revenues decline by nearly 23 percent. If HSGT fares are set at the higher air fares, HSGT ridership declines by 27.9 percent while passenger revenues increase by only 2.1 percent. With higher fares, HSGT revenues barely increase, indicating the fares assumed in the basecase are near the revenue-maximizing point.

Since the basecase uses the "aggressive" travel times, any other test of HSGT travel times will be at slower speeds. Thus, under the "moderate" VHSR scenario, HSGT ridership is estimated to decrease 27.5 percent, while passenger revenues decrease 35.4 percent. Under the slightly better "aggressive" VHSR scenario, HSGT riders decline 23.1 percent, while passenger revenues decline 29.9 percent. All sensitivity analyses assume the basecase fare at 300% rail and aggressive travel time.

Table 3-13 also shows the sensitivity analysis results for alternative HSGT frequency, access/egress times, terminal-processing times along with an assumption that auto operation costs double from their base-year levels. While the changes shown are predictable, the magnitudes of change are not as large as the factors previously discussed.

Figure 3-6 illustrates the sensitivity of annual HSGT ridership projections for TPC-6 using 2010 as a base. As expected, the results are consistent with the previous discussion.

Figure 3-7 illustrates the sensitivity of revenue projections to fare. It should be noted that ridership increases with a decrease in the fare relative to the 3-times existing (1991) rail fares. The point of maximum revenue coincides with the fare structure equal to 220% of rail fares, a point at which ridership increases approximately 36 percent over the basecase.

Table 3-13. Sensitivity Analysis of HSGT Ridership and Passenger Revenue.

Factor	HSGT Assumption	Ridership Change (%)	Revenue Change (%)
Basecase	Basecase	0	0
Fare	Rail (existing)	+ 108.8	- 22.8
	Air	- 27.9	+ 2.1
Travel Time	Moderate VHSR	- 27.5	- 35.4
	Aggressive VHSR	- 23.1	- 29.9
Frequency	1/2 - 1/2 hour (B-NB)	+ 3.5	+ 2.8
	1 - 2 hours (B-NB)	- 10.6	- 10.4
Access/Egress	+20 percent	- 5.3	- 5.7
	-20 percent	+ 5.6	+ 6.0
Terminal Time	Air	- 2.8	- 3.2
	-20 percent	+ 2.1	+ 2.4
Auto Cost (Doubling)	Basecase	+ 3.6	+ 3.7

SOURCE: Charles River Associates, 1993.

Sensitivity of HSGT Ridership to Alternative Input Assumptions

Source: Charles River Associates, 1993.

Figure 3-6. Relative to Basecase Conditions of HSGT Ridership Sensitivity to Alternative Input Assumptions.

2010 FARE SENSITIVITY ANALYSIS

Scenario: HSGT Alignment TPC-6, Induced demand method=4 , HSGT Fare = 300% of rail fare, HSGT wait = 0.25/0.50 hrs.

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HSGT Fare as a % of rail fare	Total Revenue	HSGT Ridership
Current Revenue Forecast	\$474,009,475	3,835,342
100%	\$367,721,291	8,075,425
140%	\$442,977,513	7,044,002
180%	\$485,255,698	6,088,819
220%	\$497,028,861	5,203,651
260%	\$489,065,187	4,445,297
300%	\$474,009,475	3,835,342
340%	\$453,346,921	3,326,573
380%	\$427,869,088	2,889,078
420%	\$396,384,733	2,498,526
460%	\$359,204,569	2,144,502
500%	\$320,000,263	1,831,476

2010 FARE SENSITIVITY ANALYSIS

Scenario: Tilt HSR Option, Induced demand method=4 , HSR Fare = 200% of rail fare, HSR wait = 0.25/0.50 hrs.

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HSR Fare as a % of rail fare	Total Revenue	HSGT Ridership
Current Revenue Forecast	\$266,950,563	3,425,784
100%	\$196,260,229	4,783,751
140%	\$237,956,741	4,216,440
180%	\$260,484,263	3,669,215
220%	\$271,730,011	3,208,437
260%	\$275,368,365	2,823,283
300%	\$269,980,389	2,474,775
340%	\$257,714,134	2,158,866
380%	\$241,683,448	1,878,904
420%	\$224,639,599	1,637,426
460%	\$208,593,281	1,434,134
500%	\$194,266,043	1,264,292

Figure 3-7. TPC-6 Aggressive Realignment Revenue/Fare Sensitivity.

PASSENGER DIVERSION AND ECONOMIC BENEFITS

A VHSR/Maglev system in New York State would provide significant benefits to the region more than just simply moving people faster and cheaper than existing alternatives. The system could profoundly affect travel patterns, where people live and work, where commercial, residential and industrial development occurs as well as the regional economy. More goods and services could be produced and consumed as a result of constructing and operating the system; it could increase productivity. It could relieve congestion at airports or on roadways and avoid the cost of then unnecessary improvements to other modes.

A major investment in infrastructure such as a VHSR/Maglev system may lower individual (and perhaps societal) travel costs, a major determinant of travel demand and patterns. Travel costs are a function of the out-of-pocket costs of travel, such as fares, tolls, and gasoline purchased, and the cost of time spent traveling, a product of the time spent and the value of that time that could have been spent in other productive activities. The time spent traveling not only includes the time spent in the line-haul portion of the trip in the automobile or on the aircraft, but includes the time spent accessing the facility, such as time spent en-route to stations, or at stations or airports waiting for the line-haul portion of the trip to commence.

A major question relevant to implementing a VHSR/Maglev system in New York State is if it would produce significant travel cost savings. This section examines the economic benefits associated with constructing and operating a HSGT system.

Before estimating passenger diversion to a VHSR/Maglev system, it is useful to look at the travel market in this corridor. As Table 3-14 shows, New York State's 1990 Census population of more than 17.9 million people is forecasted to grow by only 0.3 percent a year on average over the next twenty years, to more than 18.9 million people, an increase in overall population of 960,000 people over twenty years, or an average annual increase of some 50,000 people, not a significant growth market for a new transportation system. The most optimistic population forecasts, extrapolations produced by the National Planning Data Corporation, do not differ significantly from these estimates.

How do these residents travel around the State? Figure 3-8 shows the distribution of mode choices of intercity travelers along the New York City-Albany-Buffalo Corridor. The greatest proportion of trips along this corridor are auto trips: 70 percent of business trips, and 96 percent of non-business

trips are made by auto. The next most common mode of travel is air: 25 percent of business trips are made by air, and two percent of non-business trips. Rail travel is a distant third, comprising five percent of business trips and a mere 2 percent of non-business trips along the corridor.

Fares

Of the line-haul portion of travel costs, air or rail fares, and automobile-operating costs such as tolls, gasoline, and maintenance expenses, the most expensive travel mode is air. For example, the per-mile line-haul rate for business travelers is \$1.62. Rail is the next most expensive. Auto costs are the lowest. Figure 3-9 compares the HSGT fares to existing travel rates on a per-mile basis. It is assumed that the fare for all HSGT alignments and technologies is set at three times the current rail fare.

COUNTY	Extrapolated Population Projections								
	CENSUS			NYS DED Projection		Based on NPDC 1992 Proj'n		Based on NPDC 1997 Proj'n	
	1980 Pop	1990 Pop	Annual	2010	Annual	2010	Annual	2010	Annual
	CENSUS Actual	CENSUS Actual	Percent Growth 1980-1990	Population	Percent Growth 1990-2010	Population	Percent Growth 1990-2010	Population	Percent Growth 1990-2010
	1	2	3	4	5	6	7	8	9
ALBANY	285,861	292,594	0.2%	295,045	0.0%	313,380	0.3%	311,563	0.3%
ALLEGANY	51,742	50,470	-0.2%	54,027	0.3%	48,796	-0.2%	48,537	-0.2%
BRONX	1,168,785	1,203,789	0.3%	1,224,052	0.1%	1,306,179	0.4%	1,298,275	0.4%
BROOME	213,648	212,160	-0.1%	206,750	-0.1%	213,776	0.0%	212,658	0.0%
CATTARAUGUS	85,694	84,234	-0.2%	93,647	0.5%	82,835	-0.1%	82,399	-0.1%
CAYUGA	79,884	82,313	0.3%	82,804	0.0%	89,221	0.4%	88,681	0.4%
CHAUTAUQUA	146,920	141,895	-0.3%	153,330	0.4%	135,001	-0.2%	134,250	-0.3%
CHEMUNG	97,657	95,195	-0.3%	97,120	0.1%	92,442	-0.1%	91,952	-0.2%
CHENANGO	49,345	51,768	0.5%	57,202	0.5%	58,257	0.6%	57,858	0.6%
CLINTON	80,751	85,969	0.6%	99,415	0.7%	99,001	0.7%	98,246	0.7%
COLUMBIA	59,487	62,982	0.6%	78,944	1.1%	72,006	0.7%	71,478	0.6%
CORTLAND	48,820	48,963	0.0%	54,658	0.6%	50,289	0.1%	50,019	0.1%
DELAWARE	46,824	47,225	0.1%	47,938	0.1%	49,139	0.2%	48,872	0.2%
DUTCHESS	245,055	259,462	0.6%	306,157	0.8%	296,981	0.7%	294,771	0.6%
ERIE	1,015,308	968,532	-0.5%	984,665	0.1%	898,473	-0.4%	893,129	-0.4%
ESSEX	36,176	37,152	0.3%	41,483	0.6%	40,177	0.4%	39,934	0.4%
FRANKLIN	44,929	46,540	0.4%	44,504	-0.2%	50,980	0.5%	50,656	0.4%
FULTON	55,153	54,191	-0.2%	64,953	0.9%	53,951	0.0%	53,670	0.0%
GENESSEE	59,399	60,060	0.1%	65,308	0.4%	62,857	0.2%	62,515	0.2%
GREENE	40,862	44,739	0.9%	42,792	-0.2%	54,265	1.0%	53,735	0.9%
HAMILTON	5,034	5,279	0.5%	5,600	0.3%	5,823	0.5%	5,782	0.5%
HERKIMER	66,715	65,797	-0.1%	72,771	0.5%	65,150	0.0%	64,810	-0.1%
JEFFERSON	88,152	110,943	2.3%	153,700	1.6%	173,074	2.2%	168,306	2.1%
BROOKLYN	2,230,515	2,300,664	0.3%	2,254,228	-0.1%	2,492,665	0.4%	2,477,666	0.4%
LEWIS	25,036	26,796	0.7%	34,975	1.3%	31,547	0.8%	31,280	0.8%
LIVINGSTON	57,007	62,372	0.9%	71,603	0.7%	75,537	1.0%	74,811	0.9%
MADISON	65,150	69,120	0.6%	78,992	0.7%	79,139	0.7%	78,546	0.6%
MONROE	702,167	713,968	0.2%	749,600	0.2%	754,477	0.3%	750,245	0.2%
MONTGOMERY	53,438	51,981	-0.3%	55,584	0.3%	50,335	-0.2%	50,064	-0.2%
NASSAU	1,321,582	1,287,348	-0.3%	1,292,457	0.0%	1,254,003	-0.1%	1,247,334	-0.2%
MANHATTAN	1,428,268	1,487,536	0.4%	1,456,707	-0.1%	1,643,358	0.5%	1,632,772	0.5%
NIAGARA	227,353	220,756	-0.3%	223,962	0.1%	212,344	-0.2%	211,188	-0.2%
ONEIDA	253,466	250,836	-0.1%	268,392	0.3%	251,557	0.0%	250,239	0.0%
ONANDAGA	463,919	468,973	0.1%	482,729	0.1%	491,621	0.2%	488,911	0.2%
ONTARIO	88,909	95,101	0.7%	103,571	0.4%	110,936	0.8%	110,035	0.7%
ORANGE	259,604	307,647	1.7%	365,130	0.9%	429,765	1.7%	421,947	1.6%
ORLEANS	38,495	41,846	0.8%	44,599	0.3%	50,216	0.9%	49,749	0.9%
OSWEGO	113,894	121,771	0.7%	152,757	1.1%	140,971	0.7%	139,865	0.7%
OTSEGO	59,075	60,517	0.2%	65,610	0.4%	65,042	0.4%	64,660	0.3%
PUTNAM	77,193	83,941	0.8%	104,429	1.1%	100,724	0.9%	99,802	0.9%

Table 3-14. New York State Historical Population Data and Forecasts.

Market Analysis

COUNTY	CENSUS			NYS DED Projection		Extrapolated Population Projections			
	1980 Pop	1990 Pop	Annual Percent Growth 1980-1990	2010	Annual	Based on NPDC 1992 Proj'n		Based on NPDC 1997 Proj'n	
	CENSUS Actual	CENSUS Actual		Population	Percent Growth 1990-2010	2010 Population	Annual Percent Growth 1990-2010	2010 Population	Annual Percent Growth 1990-2010
	1	2	3	4	5	6	7	8	9
QUEENS	1,887,066	1,951,598	0.3%	1,953,634	0.0%	2,122,793	0.4%	2,109,849	0.4%
RENSSELAER	151,908	154,429	0.2%	162,813	0.3%	163,374	0.3%	162,458	0.3%
STATEN ISLAND	351,995	378,977	0.7%	489,111	1.3%	445,318	0.8%	441,592	0.8%
ROCKLAND	258,868	265,475	0.3%	336,209	1.2%	283,790	0.3%	282,153	0.3%
SAINT LAWRENCE	114,254	111,974	-0.2%	131,055	0.8%	109,970	-0.1%	109,394	-0.1%
SARATOGA	153,759	181,276	1.7%	196,719	0.4%	251,062	1.6%	246,660	1.6%
SCHENECTADY	149,946	149,285	0.0%	153,799	0.1%	150,822	0.1%	150,035	0.0%
SCHOHARIE	29,711	31,859	0.7%	34,877	0.5%	37,216	0.8%	36,907	0.7%
SCHUYLER	17,686	18,662	0.5%	18,721	0.0%	21,116	0.6%	20,963	0.6%
SENECA	33,733	33,683	0.0%	32,018	-0.3%	34,400	0.1%	34,214	0.1%
STEUBEN	99,215	99,088	0.0%	105,846	0.3%	101,188	0.1%	100,656	0.1%
SUFFOLK	1,284,212	1,321,864	0.3%	1,614,631	1.0%	1,428,745	0.4%	1,420,215	0.4%
SULLIVAN	65,157	69,277	0.6%	78,006	0.6%	79,634	0.7%	79,026	0.7%
TIOGA	49,812	52,337	0.5%	50,623	-0.2%	58,590	0.6%	58,198	0.5%
TOMPKINS	87,081	94,097	0.8%	105,134	0.6%	111,460	0.9%	110,491	0.8%
ULSTER	158,160	165,304	0.4%	184,139	0.5%	184,576	0.6%	183,336	0.5%
WARREN	54,854	59,209	0.8%	63,617	0.4%	70,518	0.9%	69,888	0.8%
WASHINGTON	54,795	59,330	0.8%	66,156	0.5%	71,130	0.9%	70,473	0.9%
WAYNE	84,580	89,123	0.5%	109,691	1.0%	100,721	0.6%	100,008	0.6%
WESTCHESTER	866,600	874,866	0.1%	855,771	-0.1%	910,824	0.2%	905,882	0.2%
WYOMING	39,894	42,507	0.6%	49,303	0.7%	48,948	0.7%	48,577	0.7%
YATES	21,458	22,810	0.6%	24,210	0.3%	26,208	0.7%	26,005	0.7%
STATE TOTAL:	17,562,027	17,990,455	0.2%	18,948,273	0.3%	18,358,691	0.4%	18,228,191	0.3%

Notes:

- Col 1 & 2 1980 and 1990 Census Populations were obtained from the National Planning Data Corporations's database. The numbers represent the total population of each county as defined in the 1990 Census.
- Col 4 Source: Official Population Projections for New York State Counties: 1980-2010. This data was published in 1985 by the New York State Department of Economic Development's State Data Center.
- Col 6 This set of 2010 population forecasts was estimated by PB by trending the 1990-1992 growth projections derived by the National Planning Data Corp.
- Col 8 This set of 2010 population forecasts was estimated by PB by trending the 1990-1997 growth projections derived by the National Planning Data Corp. NPDC's forecasts are based primarily on historical population trends recorded by the Census Bureau in their decennial Census and interdecennial population surveys. The forecasts also incorporate information from some state and county-level planning agencies, as well as other sources.

Table 3-14. (Continued).

BUSINESS TRAVEL

NON-BUSINESS TRAVEL

Source: Ridership estimates, Charles River Associates

Figure 3-8. Existing (1991) Trips by Mode.

Figure 3-9. Comparison of Per-Mile Line-Haul Travel Costs for All Modes.

Time Savings

Figure 3-10 compares the line-haul times of four alternatives along the entire length of the system from New York to Buffalo. There is significant variance among the alternatives.

Total travel time includes time spent getting to and from terminals and rail stations and time spent waiting for the next train or plane. In this study this is assumed to be half the headway time between scheduled trains or flights, as well as the line-haul time, the travel time spent in the plane, train, or auto. For example, an air trip from New York to Albany takes 1.05 hours; a car trip takes 3.22 hours. Comparing line-haul times, air is the faster mode. However, if one considers that the average trip from home to LaGuardia airport plus the time spent getting from Albany airport to the final destination takes 1.9 hours, and that the average wait time is about half an hour between flights for business travelers, the total air travel time adds up to 3.29 hours, a few minutes longer than the auto trip. Access and egress costs for auto travel are insignificant. CRA assumed that access and egress times were two minutes for each city pair.

Figure 3-11 shows the average total time savings experienced by passengers diverting from each of the currently used modes to each of the four HSGT options.

There are consistent travel savings for passengers diverted from existing rail. The option is the only system which saves time for all users diverted from other modes. Much of this time savings is due to short headways between trains, as well as the shorter access, egress and terminal-processing times at train stations compared to airports.

Results for auto are strongly affected by whether a car is needed at the destination, as this adds significantly to the terminal processing time, which usually includes renting a car. In general, HSGT provides positive time savings compared to autos only for longer routes. For short routes, such as Syracuse-Utica/Rome and Buffalo-Syracuse, HSGT speeds lead to time savings that are generally too small to counteract the access/egress and wait times of non-auto travel.

Figure 3-10. Comparison of One-Way Line-Haul Times by Technology Type Over the Total System Length of 464 Miles.

Figure 3-11. Average Total Time Saved for a Passenger Diverting from Existing Modes to Each HSGT Option Per Diverted Business Passenger.

Total Travel Time includes Line-Haul Time, plus Access, Wait and Terminal Time.

Value of Time Savings

Business travelers' greater use of expensive air travel confirm that different travelers value their time at different levels. To calculate the economic value of passenger time saved, the same valuation of time given in Table 3-5 by CRA for their ridership model was used. These values were derived from a survey of travelers. Table 3-15 shows the results of applying these time values to the positive time savings of diverted passengers for 1991 and Table 3-16 shows the corresponding values for 2010.

Table 3-15. Value of Travel Time Saved by Diverting to HSGT (1991).

Annual Value of Passenger Time Saved
1991

	Baseline VHSR <u>Alignment</u> (\$millions)	Aggressive VHSR <u>Alignment</u> (\$millions)	Aggressive Maglev <u>Alignment</u> (\$millions)
Value of Time Saved for Business Travelers diverted from:			
Air	\$3.992	\$1.030	\$10.120
Rail	\$8.472	\$14.539	\$24.337
Auto (car needed at destination)	\$3.503	\$9.114	\$20.955
Auto (car not needed at destination)	\$1.288	\$2.972	\$6.120
Total for all Business Travelers:	\$13.662	\$27.653	\$61.531
Value of Time Saved for Non-Business Travelers diverted from:			
Air	\$0.013	\$0.019	\$0.825
Rail	\$0.543	\$0.123	\$0.402
Auto (car needed at destination)	\$1.434	\$3.984	\$10.029
Auto (car not needed at destination)	\$1.894	\$4.968	\$11.148
Total for all Non-Business Travelers:	\$3.395	\$9.093	\$22.403
TOTAL FOR ALL TRAVELERS:	\$17.057	\$36.747	\$83.934

Values are the sum of positive values of time saved by passengers traveling within each Origin-Destination pair.

Table 3-16. Value of Travel Time Saved by Diverting to HSGT (2010).

Annual Value of Passenger Time Saved
2010

	Baseline VHSR <u>Alignment</u> (\$millions)	Aggressive VHSR <u>Alignment</u> (\$millions)	Aggressive Maglev <u>Alignment</u> (\$millions)	Incremental <u>Option</u> (\$millions)
Value of Time Saved for Business Travelers diverted from:				
Air	\$0.4	\$1.1	\$10.9	\$0.7
Rail	\$10.1	\$17.5	\$32.3	\$12.8
Auto (car needed at destination)	\$3.7	\$9.8	\$26.0	\$5.7
Auto (car not needed at destination)	\$1.4	\$3.2	\$7.4	\$2.0
Total for all Business Travelers:	\$15.6	\$31.5	\$76.6	\$21.1
Value of Time Saved for Non-Business Travelers diverted from:				
Air	\$0.0	\$0.0	\$0.9	\$0.0
Rail	\$0.1	\$0.2	\$6.2	\$0.3
Auto (car needed at destination)	\$1.5	\$4.3	\$16.0	\$6.3
Auto (car not needed at destination)	\$2.0	\$5.3	\$16.9	\$8.2
Total for all Non-Business Travelers:	\$3.6	\$9.7	\$40.1	\$14.8
TOTAL FOR ALL TRAVELERS:	\$19.2	\$41.2	\$116.7	\$35.9

Values are the sum of positive values of time saved by passengers traveling within each Origin-Destination pair.

Figure 3-12. Comparison of 2010 Per-Trip Total Travel Costs by Mode.

Safety

Safety impacts of VHSR were determined by estimating the number of accidents that would occur on trips taken by diverted passengers using their former modes. Accident costs are not estimated because data on aircraft accident costs are unavailable and estimates for HSGT accident costs are speculative. These costs, however, are indirectly reflected in insurance costs, that are included in modal-travel cost estimates.

Extensive statistics on auto accidents are compiled by the Federal Highway Administration. The data collected include the number of fatal, injury, and property-damage-only accidents. These statistics are widely used to predict the number and types of accidents based on estimating the number of vehicle miles traveled over various roadway types. Statistics on aircraft accidents are compiled by the National Transportation Safety Board and the Federal Aviation Administration. These statistics include the number of aircraft accidents and fatalities by type of service such as scheduled, non-scheduled, air carrier, commuter, and general aviation. Accident rates by mode are given in Table 3-17.

Table 3-17. Accident Rates by Mode.

Automobiles	Accident Measure	Year 2010
	Accidents per 1 million vehicle miles (MVM)	2.05
	Fatalities per MVM	0.024
	Injuries per MVM	1.77
Aircraft	(All scheduled and nonscheduled service)	
	Accidents per 100,000 departures	0.378
	Fatalities per 100,000 departures	0.068

Source: National Traffic Safety Board 1992 FSU Estimates

Estimating the safety performance of a VHSR/Maglev system is more speculative than auto or air travel. Only two VHSR systems are in operation today, the Japanese "Bullet Train" and the French TGV. The safety performance of these systems has been excellent. After 27 years of operation for the Japanese system and 10 years for the TGV, neither system has had an accident involving an injury or fatality.

While there is no certainty that the favorable safety record achieved by these systems can be duplicated in New York State the prospects are good. There are however, numerous factors that affect railroad safety including the degree of grade separation and track protection along the corridor, level of rail freight movement on VHSR tracks if any, skill level of the train operators and switch controllers, operating speed restrictions through populated areas, track and equipment reliability, and other factors. Because a system however will operate on a grade- and corridor-separated guideway, the prospects for flawless safety performance that matches the French and Japanese VHSR systems are favorable. This assumption is used in this section of the report.

In 1990, 2,032 fatal and 200,301 non-fatal accidents occurred in New York State while residents drove more than 106,902,000 miles. New York State posted a 1.90 and 187.37 fatal and non-fatal accident rate per 100 million vehicle-miles traveled respectively. It is assumed these levels will continue through 2010.

The accident death rate for national air travel has fluctuated significantly in this same period. In this analysis, the average rate for the period is used to estimate avoided fatalities and injuries. Using these rates, the number of avoided accidents, fatalities, and injuries, by diverted auto and air passengers, was estimated.

By diverting auto travelers to HSGT from autos on average, 201 automobile accidents are estimated to be avoided in 2010 with 27 fewer fatalities due to accidents, and with accident savings damages of \$3.2 million in 2010. Accidents avoided by diverting auto passengers are shown in Table 3-18.

Table 3-18. Estimated Accidents Avoided by Diverted Auto Passengers.

Year	Vehicle Diverted Autos	Annual Miles Traveled	Annual Avoided Fatalities	Annual Avoided Injured	Avoided Accidents
2010	2,024,249	240,221,572	27	201	201

*Sources: National Traffic Safety Board
CRA Ridership Estimates
FSU Estimates*

In 2010, approximately 1.33 million air passenger trips will be diverted, eliminating 30,087 aircraft flights. Based on the aircraft accident rate, one accident is avoided for every 265,000 aircraft departures. Thus, an avoided aircraft accident attributable to eliminating aircraft flights is estimated to occur in 2018. Aircraft accident fatalities occur less frequently. One aircraft accident fatality occurs for every 1.5 million departures. At the level of eliminated aircraft flights, an avoided aircraft accident fatality attributable to VHRSR diversions is expected to occur after approximately three years of operation.

Section 3-B

FREIGHT MARKET ASSESSMENT

SUMMARY

It was originally thought that VHSR/Maglev would create a market for a service providing same-day freight delivery along the proposed network. However, according to recent remarks by Federal Express CEO Frederick Smith (Boston, MA, December 7, 1992), the national market for same-day delivery is quite small, estimated to be fewer than 5 million shipments per year.

Furthermore, this study suggests the freight opportunities for a stand-alone New York State HSGT are not as encouraging as previously thought. The basic problem is that it will be difficult for a HSGT system to offer shippers a significantly higher level of service than they are already receiving, or service at a price lower than truck carriers.

Yet as the network expands into other states and regions, the opportunities for freight transport will increase accordingly. When VHSR/Maglev is able to offer next-day delivery to shippers moving freight between 500 and 1000 miles at prices below air transport, it could attract significant volumes of freight. A regional HSGT system carrying freight in the off-hours offers this potential.

To calculate the potential freight market for HSGT, it is assumed that a New York State HSGT system exists, and is integrated with intermodal expedited freight service in the Northeast and adjacent Midwest regions and that stations and cargo terminals are located appropriately according to the transport mode; i.e., at airports for air cargo; at the CBD in major cities; and sorting and handling facilities are conveniently located.

An HSGT system operating in the Buffalo-Albany-NYC corridor primarily will appeal to those shipping and transporting expedited or time-sensitive freight, one of the fastest-growing components of the freight-transportation market. This growth will continue to outpace increases in most other segments of the freight market. A survey of shippers, carriers, and freight forwarders indicate that current non-expedited freight is shipped at much slower speeds to obtain the lowest cost. It does not therefore represent a market for HSGT.

The analysis shows that in spite of the intensely competitive nature of these expedited freight carriers, a regional HSGT system has the potential to generate as much as \$231 million in freight revenues with competitive structure. Table 3-19 summarizes the results of the revenue analyses as a function of fare.

Table 3-19 Summary of HSGT Revenue from Freight as A Function of Fare.

Category of Freight	Regional Revenue	Corresponding Rates
Express Surface	\$132 Million	\$0.45
"Air" Cargo	\$ 25 Million	\$0.65
Overnight Air	\$ 45 Million	\$1.40
Under 500 lb. LTL*	\$ 29 Million	\$0.15
Total	\$231 Million	—

* Less-than-Load

Expedited Freight: Overnight versus Deferred

For this analysis, expedited freight has been categorized into two distinct service offerings: overnight and deferred service. Overnight service, involves an evening pickup with delivery assured the following business day, at a premium price. Colography Group data indicate nearly \$13 billion in revenue nationally in 1991, based on volume of more than seven billion pounds for 650 million shipments.

Deferred service, offers expedited delivery within two to three business days to shippers who either do not require guaranteed overnight transport or are unwilling to pay the additional cost. This sector of the expedited-freight market, six times larger than the overnight segment is slightly more lucrative. Nationally, it generated almost \$15 billion dollars on 2.5 billion shipments weighing 42 billion pounds.

Type of Expedited-Freight Carrier

The expedited market is differentiated by the type or mode of carrier providing the service. Based on previous studies, the analysis was narrowed to the three types of expedited-freight transportation most likely to use the VHSR/Maglev option:

- Express Surface (such as UPS, Roadway Package);
- "Air" Cargo (such as Federal Express, DHL, Airlines with freight forwarders); and
- Under 500 Pound Less than Truckload (LTL) (such as Roadway, Yellow Freight).

Diversion Model Based on Cost-of-Service

Based on modal and regional segment data from the Colography Group, a VHSR/Maglev diversion model that was primarily a function of the cost of the service was created. Diversion estimates considered only changes in relative transport prices, given a line-haul speed that far exceeds trucks in the same corridor and is at best equal to air service.

There is no meaningful method to translate other potentially differentiating characteristics, such as train scheduling and station access, into diverted volumes and revenues. Train scheduling cannot be used because VHSR/Maglev schedules have not been determined with enough specificity. Station access cannot be considered because the accessibility of the system's stations is unknown and because their locations are as yet undetermined.

Assumptions

It was assumed that:

- The system's scheduling will be convenient to shippers and its stations will be relatively accessible, given the conditions previously described; and
- there will be differences in shipping rates charged by each mode, to the extent that the proposed system may have advantages or shortcomings in a particular service area.

The problem is one of standard equilibrium analysis; that is, to establish a relationship of modal market share to cost-per-pound, and estimate the volume of freight that would be diverted to VHSR/Maglev for a variety of rate scenarios.

The foundation of the analysis for this comparison of known services (air and truck transport) to a non-existent service is not built on hard data. Rather it depends on anecdotal information gathered from interviews with express-freight transporters. They were asked if they would be willing to pay,

say five percent more for intercity linehaul transport if service levels improved by something more than five percent, without defining the precise magnitude of the service improvements.

Regarding freight diversion, it was assumed that:

- VHSR/Maglev would divert half the potential traffic at the same linehaul rates; and
- The amount of freight diverted to VHSR/Maglev on a percent of total basis for any given rate scenario is the same for all cities in the target region regardless of their geographic proximity to the VHSR/Maglev network.

For example, the model assumes that 50 percent of all Buffalo to New York traffic, and 50 percent of Chicago to New York traffic diverts to VHSR/Maglev at rates equal to those of alternative modes. This is assumed although a freight move to New York via VHSR/Maglev from Chicago would first require an interim journey to a terminal of the system, which in this case would likely be in Buffalo.

It is likely that the percent of freight diverted to VHSR/Maglev for any given modal rate ratio (vs. conventional mode) will depend on the city's proximity to the network. The diversion levels reflected in the model are a composite average of the various diversion levels likely to result for any given rate scenario.

The Just-in-Time Factor

While there is a strong trend toward just-in-time manufacturing, it appears that more reliable, not faster, transport is required. A just-in-time operation requires that in-bound materials arrive on time, not that they be transported quickly.

In the past, when transport was less reliable, speed made up for the unreliability inherent in the system. The overall reliability of truck transport has increased tremendously as shippers and carriers become more sophisticated in their planning and develop more advanced information systems. As a result, the primary growth area in expedited- freight transportation is not in transporting overnight products, but in second-day and other deferred products.

EXPRESS-SURFACE FREIGHT

The majority of expedited freight moving within the Buffalo-Albany-New York region is express-surface freight, reported by the Colography Group to have earned revenue of \$3.0 billion nationally on 748 million shipments in 1991. Express-surface freight also is the largest market in terms of potentially divertable revenue. This could be as high as \$132 million at a \$0.35 per pound rate as shown in Tables 3-13 and 3-14.

The Speed Factor

The fundamental problem with an VHSR/Maglev limited to the Buffalo-Albany-New York corridor is that the system offers only incremental improvements over the present level of service. The only differentiating service characteristic that can be clearly assigned to the hypothetical high-speed system is that its average speed will be greater than truck travel. Yet its speed edge may not be much of an advantage in a corridor where overnight truck delivery is possible which is about as quick as most shippers ever require.

Any speed advantage VHSR/Maglev might have relative to truck service could be negated by the cost disadvantage. Express-surface providers strive to provide overnight air service at a much lower price. Even so, most express freight moving in the target area is delivered on a second-day basis. Most shippers choose to pay a lower price for less urgent delivery. There appears to be no perceived value added when the freight arrives at destination at 1 A.M. rather than 5 A.M. or 6 A.M. Often, no one is there to meet the delivery in the middle of the night.

The Cost Factor

In addition, up to 70 percent of the total cost to the shipper is pickup and delivery, not line haul. While the actual structure of VHSR/Maglev freight rates is unknown, its linehaul charge will undoubtedly cost shippers more than they presently pay for the line-haul component of express-surface truck service.

That being likely, if the system is to divert traffic from competing modes it must identify a segment of the freight-shipping population willing to pay a premium rate for the same service heretofore delivered at very low prices.

AIR CARGO: OVERNIGHT AND DEFERRED

This segment earned about \$1.4 billion nationally on 13.2 million shipments, according to data from the Colography Group. The air overnight sector is the more lucrative of the two air markets from a diversion perspective. Overnight air yields \$45 million at a \$1.40 rate, while deferred air offers yields of approximately \$25 million given a \$0.65 per pound rate.

"Air" Cargo Moved by Truck

The term "air" cargo may be misleading, for a significant portion of "air" cargo moving between the cities along the proposed VHSR/Maglev network is actually transported by truck. Moreover, transporting "air" shipments by truck is not a regional phenomenon. Indeed, it is common knowledge to most transportation analysts that a significant amount of "air" cargo never leaves the ground. For this study, "air" cargo has been defined as that which is sold to shippers as an implied air-freight product, with all of the features air service includes, even if intercity linehaul is actually provided by truck.

The Distance Factor

Interviews with industry leaders in the air-freight sector indicate that carriers move overnight air freight whenever they have the opportunity. The feasibility threshold for the surface transport of air freight naturally varies by region, although most carriers prefer truck travel if intercity transport can be completed within nine hours, 400 miles or so.

Therefore, any VHSR/Maglev system would be forced to compete with the cost structure and service levels of intercity trucking for air freight moving less than this distance. Yet as shipment distances begin to extend beyond the 400-mile range, overnight delivery usually involves an air link.

VHSR/Maglev would certainly become a viable alternative over longer distances, assuming a rate structure competitive with air linehaul. An extensive VHSR/Maglev system would likely be well-positioned to exploit the niche market of providing intercity air-freight service with guaranteed overnight delivery for movements between 500 and 1000 miles at a lower price than air linehaul delivery.

UNDER 500 POUND LESS THAN TRUCK LOAD (LTL)

It is reasonable to consider the smaller LTL shipments as expedited freight and, hence, potentially divertable to a VHSR/Maglev system, given the relatively short distances and travel time between cities within the Buffalo-Albany-NYC corridor. Most cargo in this segment can be categorized as deferred traffic, with delivery assured usually by the second business day after pickup.

Timeliness and Service

On balance, LTL traffic is as time-sensitive as other categories of expedited cargo, which is not to say that speed is unimportant, but rather that timeliness is paramount. Intense competition within this sector has benefitted shippers with low prices, although it is unlikely rates will decline much more. Carriers now distinguish themselves by offering premium service. In this regard a VHSR/Maglev system may have unique advantages because it operates over a dedicated system with no external interruptions.

There may be a niche for a VHSR/Maglev system able to offer reduced transit time without compromising scheduled pickup and delivery times, and do so at a competitive price. This is an intensely competitive sector with very low rates, likely making this an unattractive market for VHSR/Maglev operators. For example, data from the Colography Group data indicate this sector generated slightly less than \$700 million nationally in 1991. Accordingly, our model estimates that a rate of \$0.15 per pound will earn VHSR/Maglev only \$29 million annually as seen in Tables 3-20 and 3-21 and Figure 3-13.

Consolidation and Sorting

Another major obstacle VHSR/Maglev must overcome is that small-lot LTL operations require significant break-bulk and sorting facilities. Consolidation and sorting expenses are a much higher percentage of an LTL carrier's total operating cost than linehaul costs. Given the economies-of-scale opportunities inherent in sorting operations, LTL firms typically construct one large facility to service a wide geographic area. Firms find that it is much more economical to transport freight long distances to a single-sort facility rather than site numerous smaller sorting centers closer to the cities generating the freight.

For instance, one of the nation's largest carriers consolidates all its New York City area freight in Harrisburg, PA. The cost savings would have to be fairly substantial to induce the carrier to bring the freight back to the VHSR/Maglev system for intercity linehaul transport along the proposed NYC-Albany-Buffalo corridor.

VIABILITY OF THE VHSR/MAGLEV LINE-HAUL OPTION

Interviews with freight transporters and forwarders in all sectors of the expedited market generated a list of common concerns and service requirements. These comments are made from a perspective of current market status and may not account for implicit changes in the market should the HSGT system be constructed and potentially provide a competitive option for time sensitive materials.

- VHSR/Maglev scheduling must coincide with the carriers' local pick-up and delivery constraints. Shipments are usually gathered for consolidation in the late afternoon and early evening and transported intercity at night, with delivery to the customer expected by the following or second morning;
- Some carriers would conceivably pay a premium for faster service; however VHSR/Maglev rates should generally be competitive with current intra-regional linehaul rates;
- Carriers and forwarders anticipate increased handling costs associated with VHSR/Maglev linehaul, which could only be rationalized by lower linehaul costs; i.e., VHSR/Maglev rates and/or "better" service, such as faster, more reliable delivery; and
- Terminal sites near a major airport are preferred to those in city centers, although one major carrier did express an interest in an additional terminal in Manhattan.

Detailed listings of shipments and revenues as a function of rates and shipments, and revenues by each major city investigated along the alignment, and regional extensions are provided in the appendix.

Figure 3-13. Summary Graph of Revenues Varying as a Function of Shipping Rate for Different Freight Categories.

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Section 4

ENVIRONMENTAL ISSUES AND CONCERNS

For the purposes of this study, the environmental analysis did not attempt to address detailed site and specific environmental issues, but focuses on those issues which could have proven to be a fatal flaw. Based on the results of the analyses, there are no fatal flaws. Analyses stress the potential benefits in air emissions and estimates of energy usage and evaluate the relative noise levels and impacts of the steel wheel and Maglev systems. It is recognized that a full environmental impact statement will be required when the technology and corridor for implementation are selected.

It is critical to the project implementation schedule to schedule the environmental impact statement in relation to the project implementation schedule and in terms of the State's deadline to establish clean air attainment status. With that in mind, the following discussion outlines the regulatory process and typical time requirements for each procedure.

There are numerous levels of government which may have jurisdiction over a project of this scale. While environmental regulations are not the only significant concern, they are most frequently the source of controversy and conflict. As such, environmental concerns will have to be addressed early in the planning process, and sufficient time allotted, in developing project schedules, to mandate public notice, review periods, and public hearings. In accordance with New York State's Uniform Procedures Act, those time frames amount to anywhere from 75 to 150 days if no public hearing is

required. If a public hearing is needed, a final decision could add another 3 to 6 months. All times will vary depending on the type of permits required and the complexity of the issues to be resolved.

While there are environmental protection programs at virtually all levels of government, the primary focus of early environmental planning should be aimed at the jurisdictions which fall under the State Department of Environmental Conservation. They include: activities in freshwater wetlands and all of the State's waters; hazardous waste sites; mining for topsoil, sand, gravel or stone; construction and demolition disposal sites. Other State agencies involved in coordinated review include the Office of General Services, Department of State, Department of Transportation, and Thruway Authority, and the Office of Parks and Historic Preservation. Review by all State agencies and all other levels of government in New York State is coordinated pursuant to the State Environmental Review Act and the Uniform Procedures Act.

Detailed environmental evaluation is deferred to such time as the specific corridor is selected and the preliminary engineering sets the footprint of the track or guideway. The focus of the discussion is the issues and relative impacts and benefits of VHSR or Maglev system if constructed across New York State in the respective rail and Thruway corridor. The primary issues of concern are noise, the levels of electromagnetic fields and the status of this research, the potential reduction in air emissions and potential energy savings.

ENERGY

Fully electrified rail or Maglev guideways will add significantly to the requirements of the power grid. Investments in capital equipment will be required to supply power the length of a new VHSR track or guideway. Incremental rail for New York State envisions a non-electric locomotive, powered by fossil fuels, at least in the earliest stages. With available funding, electrification may be pursued where new track alignment also is justified to achieve speeds over 150 mph.

Energy requirements for each technology were made based on performance simulations of equipment with characteristics similar to the X-2000, and to the TGV, and the Transrapid 07 (Table 4-1). The VHSR and Maglev estimates are presented below for the most aggressively realigned route of the rail and highway alignments, respectively. In each run, stops were made at each major metropolitan area assuming acceleration and deceleration for stations and speed limiting curves assumed maximum allowable rates. Data from the "modified X-2000" simulations indicate that energy needed was lower because the higher speed was maintained over a greater portion of the trip

by reducing the frequency and degree of decelerations and accelerations into and out of curves. The X-2000 and Maglev runs suggest that tilting is beneficial in terms of energy consumption.

The evaluation of the energy merits of electrified HSGT begins with the characteristics of the originating power generating system. Electrical power for a HSGT system may be supplied by the State's investor owned utilities, the State Power Authority, independent power producers, or the HSGT operating entity itself.

Currently, New York State enjoys a surplus of electric power generating capacity; however, by 2006, the time frame within which a new HSGT system may become fully operational, new power generating capacity will be required. New capacity may in fact be required as early as 2002, dependent upon the future of the State's economy, success of Demand Side Management (DSM) conservation activities and the rate at which fossil fuel plants are retired to meet compliance with the Clean Air Act amendments.

The State's existing generating capacity consists of a mix of nuclear, hydro, natural gas, oil and coal energy sources. The State's aging coal and nuclear plants are scheduled for near-term retirement. It is anticipated that by the year 2000 as much as 4,000 MW of fossil steam generating capacity will be retired. Although there is the potential to replace this capacity with hydro power purchase from neighboring Quebec, the State's energy planners currently anticipate the new capacity will be provided by natural gas-fueled combined-cycle power plants.

The energy analysis included in this report reflects the fact that a new electrified HSGT system will be powered by electricity generated by the required new facilities. For the evaluation, the efficiency and emission characteristics of proven, natural gas fueled, combined-cycle power-generating equipment is compared against an anticipated 36 mpg fuel efficiency for automotive vehicle travel and against state-of-the-art short-haul jet air equipment.

The characteristics of the natural gas combined-cycle plant are defined as: overall plant heat rate of 9,000 BTU/KWh (equivalent to a thermal efficiency of 37.9 percent); net power plant emissions of zero lbs/MMBTU SO₂, 0.42 lbs/MMBTU NO_x, 0.003 lbs/MMBTU particulate and 110 lbs/MMBTU CO₂. Electrical power distribution losses from the generating station through the HSGT switch gear and inverter/transformer network are assumed to provide an additional 5 percent loss thereby providing useful energy to the HSGT vehicle at a net efficiency of 33 percent.

The energy efficiency of the HSGT equipment is dependent upon specifics of the technology. Maglev has the advantage of avoiding rolling resistance losses. However, there are significant differences in the magnetic drag coefficients and stator losses associated with different Maglev technologies. These differences have resulted in variations in calculated energy efficiency between different Maglev system conceptual designs. Only the German Transrapid and Japanese MLU systems have actual test operation experience. This study uses for its base the Transrapid characteristics with a 5 car configuration.

For all HSGT technologies considered the factors which dominate the energy efficiency are:

- Speed - the predominate energy consuming factor is aerodynamic drag, the faster the vehicles travel the more energy is required to overcome this resistance;
- Number of vehicles - the energy intensiveness of a single vehicle is approximately the same as short haul aircraft; additional vehicles are entrained behind the first and can significantly reduce the effective aerodynamic drag on a per-seat basis. As an example, the TR07 in a two-car consist requires approximately twice as much energy per seat as the TR07 in an eight-car consist; and
- Accelerations - the specifics of alignment curvature, and the frequency of accelerations required to regain speed after the curves and station stops influence overall energy consumption of the technology.

In the case of the incremental rail option, a distillate fueled gas turbine engine is assumed to provide the locomotive power. This equipment does not exist and assumptions have been made to provide order of magnitude estimates of energy efficiency. The generic characteristics of a 4000 hp state-of-the-art gas turbine engine having a heat rate of 9000 BTU/hp at design power rating is used. The apparent low energy efficiency of this technology is the result of the fact that electrical power plant efficiency is not factored (as it is for the electrified technologies) in and the part load efficiency (as is required for the maintenance of cruising speed vs. the installed power for acceleration) of current gas turbine technology is low.

The estimated average fuel consumption rate of a passenger car in 2010 (36 mpg) was used to estimate the gross energy consumption of the auto mode. Vehicle occupancy rate of 1.4 and 2.8 were used to determine the relative efficiency of business and non-business travel. The fuel

consumption rate of a Fokker F28 was used for the air mode. The F28 is a jet aircraft with a seating capacity of 75. This is about the average size of those aircraft currently providing service between the cities in the New York Corridor. Based on industry statistics, it is assumed that 44 seats (60 percent) would be occupied on an average flight.

Energy consumption of the Maglev system was estimated using data from a series of reports produced at Argonne National Laboratory contracted for by the U.S. Department of Energy. The energy consumption rates per occupied seat mile of the air and VHSR modes include a penalty for the energy consumed during facility access (i.e., travel to and from the airport or VHSR station). It was assumed that each passenger will access VHSR stations or airports by auto (one passenger per auto). Access travel distance is the same used in the computation of access travel costs, as previously discussed. With an average access travel distance of 19.5 miles (average access time of 39 minutes at 30 mph), 0.83 gallons of gasoline will be consumed during each passenger's facility access.

Table 4-1. Estimate of Energy Requirements from Simulation Runs.

Run No.	Alignment Condition	Max. Speed (mph)	Avg. Speed (mph)	Specific Energy kWh⁺	Total[*] Energy Required BTU/Seat-Mile
X-2000	Existing Rail	150	99	0.101	2,296
1 VHSR	Existing Rail	200	96.2	0.105	1,086
3 VHSR	Moderately realigned	200	101.8	0.107	1,107
5 VHSR	Aggressively realigned	200	116.1	0.107	1,107
2 Maglev	Existing Thruway	300	158.1	0.119	1,230
4 Maglev	Moderately realigned	300	173.8	0.126	1,303
4a Maglev	Moderately realigned	300	154.8	0.111	1,148
6 Maglev	Aggressively realigned	300	186.9	0.131	1,354
Automobile (1.6 passenger/car)	--	--	55	--	2,182
Air (75 % occupancy)	--	--	--	--	5,346

^{*}Excludes power plant efficiency and combustion engine efficiency.

⁺Includes power plant efficiency and combustion engine efficiency.

The savings in gasoline consumption result in the additional benefit of reduced foreign oil imports. Data provided by the U.S. Energy Information Administration indicate that nearly 51 percent of petroleum consumed in the U.S. is provided by foreign sources. Thus, VHSR implementation could result in reduced foreign gasoline imports of 8.9 to 17.4 million gallons in 2010. Reducing foreign imports strengthens the nation's energy independence, reduces the nation's trade deficit, increases domestic security, and reduces the vulnerability of the U.S. economy to international economic fluctuations.

Based on these assumptions, the energy consumption rates per occupied passenger seat mile are as follows: Maglev is generally more energy efficient, consuming 835 BTUs per occupied passenger seat mile (operating at 250 mph) compared to 5,346 BTUs for air (at 150 mph), and 2,182 BTUs for auto trips, respectively. In addition, Maglev will operate at a speed that is three times faster than the private auto. Though not as fast as air travel, VHSR will be significantly more energy efficient.

The resultant energy efficiency of each mode is largely affected by occupancy levels. The difference in energy efficiency will ultimately lead to a reduction in gasoline consumption. The number of gallons of auto and aviation fuel saved by diverting passengers was estimated, and is shown in Table 4-2. These values, it should be pointed out, are not net of the oil that would be needed by power plants to generate electricity for VHSR. Maglev is estimated to reduce gasoline consumption by 17.4 million gallons by 2010 (4.7 million gallons from eliminated auto trips, 12.6 million gallons from eliminated aircraft flights and 0.11 million gallons from reduced conventional rail use).

Table 4-2. Gasoline Saved by Diverted Auto and Air Passengers.

Mode	Gallons
Automobile	4,663,180
Air	12,614,396
Rail	108,256
Total	17,385,832

*Sources: Federal Highway Administration, Statistics Division FAA LACO
Engine Exhaust Emissions Databank FSU/CUTR Estimates*

AIR QUALITY

The principal pollutants from emissions are: carbon monoxide, carbon dioxide, ozone, nitrous oxides, sulfur oxides, and particulates. Sources of air pollution along the study area corridor vary by location. Area sources, such as motor vehicle traffic, account for most of the air pollution in the corridor. Industrial sources are significant in some locations, including metropolitan New York City, Albany, and Buffalo.

An examination of pollution rates of autos, aircraft, and the electrical generation grid feeding New York State that would service the high speed ground transport corridor was undertaken to determine VHSR's potential impact on pollution emissions. Emission rate statistics for autos and aircraft were obtained from both national and New York State experts, the Environmental Protection Agency and sources in the Federal Government and Argonne National Laboratory. New York State agency experts and project researchers concluded that the most reliable 2010 New York transportation mode emissions source are those provided by the U.S. Department of Energy and the Argonne National Laboratory model simulations developed for North American Electric Reliability Council (NERC) regions.

Total emissions were calculated for each mode based on estimates of the number of eliminated auto trips and aircraft flights. Emissions generated from VHSR operation were estimated by developing ratios of train energy consumed by corridor segment to the proportionate pollution loading output of planned power plants located along the corridor.

As shown in Table 4-3, there would be significant reductions in all air pollutant emissions by diverting air and auto passengers to VHSR. By 2010, the total reduction in air pollutant emissions will be over 110 thousand tons. The greatest impact on pollution will be on carbon dioxide levels. Diversion to a HSGT system also is forecast to reduce NO_x by 323 tons, sulphur dioxide by 323 tons, volatile organics by 99 tons, total suspended particulate by 35.7 tons and tire particulate by 3 tons.

**Table 4-3. Emissions Reductions for VHSR and Maglev with Resulting Savings
from Passenger Diversions (New York-Intrastate Ridership Only).**

	Tons Per Year Saved		Externality* Values	Maglev	TGV
Pollutant	Maglev	TGV	\$/Ton	\$/Savings	\$/Savings
SO ₂	23	32	\$1,324	\$ 30,452	\$ 42,368
NO _x	323	442	6,320	2,041,360	2,793,440
CO ₂	110,185	185,094	25	2,754,625	4,602,350
VOC	99	136	3,850	381,150	523,600
TSP	36	50	3,850	138,600	192,500
Total Cost Savings:				\$5,346,187	\$8,154,258

* The values for externalities are referenced by the New York State Energy Research and Development Authority, 1992, *State Energy Plan*.

The term "externality cost" is used in this study to mean what economists refer to as unpaid "damages" caused by the combustion of fossil fuels. Variables such as fuel type, pollution controls, health risk, population exposed, discount rate and other factors affect the unpaid environmental costs. Because of the variable involved, the "externality costs" per ton of specific emissions may vary from region to region or State to State.

The values used in this Report reflect recently (1992) evaluated¹ externality values for electrical power plant generation used in comparing power plant alternatives such as hydro, coal, oil, and natural gas energy sources in New York State. They are used to help quantify the value, otherwise not captured, of alternative, electrified transportation technologies considered in this study.

Ozone, the principal component of photochemical smog, is formed in the atmosphere through a series of reactions involving hydrocarbons and nitrogen oxides in the presence of sunlight. Substantial ozone concentrations are normally produced in the summer, when insolation is greatest

¹ Hydro-Quebec Economic Study, New York State Energy Office, Department of Public Service.

and temperatures are high. Hydrocarbon levels are considered the critical and limiting factor in ozone formation; control strategies for ozone focus on reducing hydrocarbon emissions.

Carbon monoxide (CO) is a product of incomplete combustion, and it is generated by transportation sources and other fuel-burning activities (like space heating). Carbon monoxide usually is one pollutant of concern related to transportation sources. It is the pollutant emitted in the greatest quantity for which short-term health standards exist and whose impact usually is localized. The highest ambient concentrations of CO accumulate near congested roadways and intersections during periods of low temperatures, light winds, and stable atmospheric conditions.

Since the U.S. Environmental Protection Agency Region II has agreed to redesignate Syracuse as attainment area for the carbon monoxide, New York City is now the only non-attainment area in New York State for this pollutant. New York City is required to use oxygenated fuel during the winter and to develop an enhanced inspection and maintenance program if the area is to meet the December 31, 1995 attainment date.

Transportation sources are often the dominant source of precursors to ozone formation. Ozone (O_3) is a highly reactive form of oxygen created by sunlight-activated chemical transformations of nitrogen oxides and volatile hydrocarbons in the ambient air. Unlike carbon monoxide, ozone problems tend to be regional in nature because the chemical reactions that produce ozone in the atmosphere occur over time. During the lag time between emission and ozone formation, ozone precursors can be transported far from their sources.

New York City lies within a "Severe Seventeen" non-attainment area for ozone and must meet some very stringent requirements if the area is to meet the November 15, 2007 attainment date. For the non-attainment area, which extends far beyond the limits of New York City, the State must show a 15 percent reduction in hydrocarbon emissions between the baseline date November 15, 1990 and November 15, 1995 (averaging 3 percent per year). Further, the state must show a 3 percent reduction per year in the ozone precursors from 1996 to the attainment date, based upon the results of the photochemical modeling demonstration.

The non-attainment area around New York City extends beyond the central metropolitan area, east over Long Island, north along the Hudson River Valley, and west. There are five marginal non-attainment areas besides New York City: Buffalo-Niagara Falls, Albany-Schenectady-Troy, Jefferson County (Watertown), Poughkeepsie, and Whiteface Mountain. These areas must meet attainment by

November 15, 1993. New York State DEC is currently developing a State Implementation Plan (SIP) that would redesignate these areas as attainment for ozone. In the last four years, (1988-1992), ozone levels have not exceeded the standard in the marginal non-attainment areas and the use of reformulated gasoline statewide should help reduce ozone precursors during the summer season.

Beneficial impacts should be realized through reduced automobile traffic along the NYS Thruway corridor and a shift from the internal combustion engine to electrical power. On a "passenger per mile" basis, reduced automobile usage should result in a net saving in energy consumption within the region. The savings should include a net reduction in fossil fuel needs as electrical power generation would, in part, be supplied by hydroelectric and, possibly, nuclear sources. Reduced reliance on fossil fuels and reduced traffic along the NYS Thruway corridor also should result in a net reduction in automobile emissions and a net benefit to air quality throughout the state.

Fine particulate matter (PM₁₀) also is emitted in vehicle exhaust and generated by tire wear, but the amount of PM₁₀ generated by individual vehicles is small compared with other sources (e.g., a wood-burning stove). Sulfur oxides (SO₂) and nitrogen dioxide (NO₂) also are emitted by space heating and motor vehicles, but concentration of these pollutants generally is not high except near large industrial facilities.

Air Quality Regulation

Air quality usually is characterized by comparing measured or calculated air pollution levels with the ambient standards established to protect human health and welfare. Areas where pollutant concentrations are lower than the ambient standards are in compliance with these standards, and air quality is considered good. These areas are considered "attainment" for the pollution that meets the ambient standard. Geographic areas where concentrations of a particular pollutant exceed the National Air Quality Standards (NAQS) are classified as non-attainment for that pollutant. Federal regulations require states to prepare state implementation plans (SIPs) that identify emission reduction strategies for non-attainment areas.

Some of the federally defined "criteria" pollutants are subject to two types of standards. "Primary" standards are designed to protect health with an adequate margin of safety, while "secondary" standards are established to protect the public from any known or anticipated effects associated with these pollutants, such as soiling, corrosion, or damage to vegetation.

The air quality standards for particulate matter, ozone, and carbon monoxide permit one exceedance of the standard each year. For carbon monoxide, the second-highest 1-hour and 8-hour average concentrations are compared with the ambient standard to determine compliance. For particulate matter, the second-highest 24-hour average concentration usually is the limiting standard. For ozone, an average of one exceedance per year during the most recent three years is permitted.

Portions of the study area corridor are designated non-attainment for these various pollutants. This reflects a regional planning challenge. For carbon monoxide non-attainment area, EPA has developed a list of Reasonably Available Control Measures that can be applied to transportation sources. This list includes motor vehicle inspection and maintenance (I&M) programs, public transportation improvements, park-and-ride lots, parking management, and traffic flow improvements. The HSGT project would be expected to contribute to a reduction in vehicle emissions by reducing vehicle-miles-traveled in the NYS Thruway corridor between New York City and Buffalo/Niagara Falls. Thus, the HSGT could be counted as part of New York's SIP, and part of regional and local air pollution mitigation programs.

It is important to recognize that intercity transportation accounts for only part of transportation pollution problems and other environmental issues associated with transportation. Intercity transportation represents a small percentage of total travel within our society. The longer distances associated with intercity travel and the potential for moving a larger number of people represents an opportunity for conserving energy and other resources, but this potential is not automatic and it varies greatly with individual technologies and applications.

Projected Air Quality Impacts

Because the HSGT would be electrically powered, the vehicle itself would not be a source of air pollution. The HSGT may reduce regional vehicle emissions by displacing automobiles from the NYS Thruway corridor. If the number of vehicle-miles-traveled (VMT) is reduced compared with a No-Action scenario, the HSGT would provide an air quality benefit. The HSGT system could have an additional effect if it also contributes to a reduction in air traffic within the region. While air travel vehicles do not contribute to regional air quality problems in the same way as do private automobiles, fuel efficiency per passenger for planes is lower than it is for HSGT systems and airport emissions are significant air pollution contributors in the State's non-attainment urban areas. If people travel within the study region by HSGT instead of by air, the consequent reduction in air traffic would relieve pressures on limited capacity air travel systems to allow remaining air traffic to

operate more efficiently. The potential for market shifts is discussed in greater detail elsewhere in this report.

Although NYS Thruway traffic may be reduced, the HSGT system vehicle is likely to generate additional traffic near train stations. Traffic congestion and air pollutant emissions would depend on conditions near each station, and can not be quantified at this time. A small but noteworthy factor to be considered in this equation is the replacement of long terminal-to-destination trips (usually by automobile) with shorter station-to-destination trips (often possible by mass transit). In general, patrons using stations located in urban or employment centers are more likely to arrive on foot or by way of transit. Patrons using stations in areas with low population density would be more likely to arrive by car. In these low-population areas, local impacts are likely to be less pronounced. Air quality impacts at each station would have to be investigated individually when station sites are selected and patronage estimates are refined.

Mitigation Measures

Because there would be a net reduction in emissions from transportation powered with electrical energy generation, the HSGT project would generate air quality impacts only near stations. Air quality impacts would be minimized by ameliorating traffic congestion near stations. Along with those emissions in Table 4-3, carbon monoxide and tire particulate are reduced with diversion from auto to rail or Maglev.

Regional Environmental Implications

The magnitude of air quality improvement is a function of the number of passenger miles which are diverted from the more environmentally destructive air and auto transportation modes to a HSGT system. Ridership in the corridor is maximized with a system which has regional extensions. Regional residents would benefit from a reduction in pollutants which would result from the implementation of a New York State HSGT system, and New York residents could benefit from the air quality improvements resulting from regional extensions to the system.

Ridership projections show that a system which regional extensions will attract more than five times the passenger miles than a New York State stand-alone system. This suggests that a system with regional extensions would produce about five times the air quality benefits of a New York intra-state system.

HSGT NOISE AND VIBRATION

Noise and vibration are often a major concern of residents and business owners along a new transportation corridor where new or increased service levels are planned. Heightened interest occurs when the new source is one of the new high speed ground transportation modes such as VHSR or Maglev. This section summarizes the noise and vibration characteristics of these new modes.

As shown in Figure 4-1, the range of interest for ground-borne vibration is from approximately 50 dB to 100 dB. In contrast to airborne noise, ground-borne vibration is not a phenomenon familiar to most people. The background vibration in residential areas is usually 50 dB or lower, well below the threshold of perception for humans which is around 65 dB.

Most perceptible indoor vibration is caused by sources within buildings such as mechanical equipment or doors slamming. Typical outdoor sources of perceptible ground-borne vibration are construction equipment, steel-wheeled trains, and traffic on rough roads. If the roadway is smooth, the vibration from traffic is rarely perceptible. Noise emanating from a passing train or Maglev vehicle is transmitted as airborne noise or as ground-borne vibration and noise.

Definitions: The following definitions are provided to familiarize the reader with the industry terms:

Decibels (dB): Both sound and vibration are expressed in terms of decibels.

Equivalent Sound Level (L_{eq}): Because environmental noise fluctuates from moment to moment, it is common to condense all this information into a single number, called the equivalent sound level. L_{eq} is a measure of the exposure resulting from the accumulation of A-weighted sound levels over a particular period of interest. Conceptually, L_{eq} may be thought of as a constant sound level over the period of interest that contains the same sound energy as the actual time-varying sound level with its normal peaks and valleys.

Maximum Sound Level (L_{max}): This is the maximum sound level of a transient noise event. L_{max} is used to characterize a particular noise source, often in specifications and design criteria.

Sound Exposure Level (SEL): The fact that SEL is a cumulative measure means that:

- Louder events have greater SELs than do quieter ones;
- Events that last longer in time have greater SELs than do shorter ones; and
- Day-Night Equivalent Sound Level (L_{dn}).

The sources differ in where they occur on the system (Figure 4-2, 4-3, and 4-4) and in what frequency range they dominate. Airborne noise from an incremental rail technologies' VHSR system is generally dominated by three sources:

- The propulsion and auxiliary equipment;
- Mechanical/structural radiation; and
- Airflow moving past the train.

Propulsion Noise Sources

Incremental rail technologies in the context of this report are assumed to be non-electric or diesel-powered locomotives incorporating turbo diesel with certain designs. Sources of propulsion noise are the diesel engines, cooling fans, and control units.

High speed trains are electrically powered. The propulsion noise sources are those from electric traction motors or electromagnets, control units and associated cooling fans. Fans have been found to be a major source. On conventional trains, major cooling fans are located near the top of the power cars, about 10 ft above the rails, as indicated in Figure 4-4. They dominate the noise spectrum in the frequency bands near 1000 Hz. External cooling fan noise tends to be constant with respect to train speed, although some traction motors have internal cooling fans that rotate at the same speed as the motors.

In a Maglev system, noise from the propulsion magnets is a result of induced vibration from magnetic forces. One source of vibration in a EDS Maglev system is oscillating magnetostriiction, which is likely to be tonal in character. Another effect of magnetic traction is sound at the pole passing frequency. The interaction of the moving vehicle and the stationary magnetic poles at a uniform spacing causes a tonal sound that varies as the velocity. These forces are located at the magnet gaps between the vehicle and the guideway. Sound radiation can come from the gaps as well as from larger structures (vehicle panels, guideway, etc.) caused to vibrate in response to such forces.

Mechanical Noise Sources

These sources include the effects of wheel/rail interaction on high speed trains, guideway structural vibrations, and vehicle body vibrations wheel/rail interaction is the rolling noise radiated by steel wheels and rails caused by small roughness elements in the running surfaces. This noise source is

close to the rockbed with an effective height of about 2 feet above the rails (Figure 4-4). Consequently, wheel/rail noise can be effectively shielded by low barriers.

Wheel/rail noise is concentrated in the frequency range of 2000 Hz to 4000 Hz and increases in level at a rate of approximately 30 times the logarithm of train speed (expressed as $30 \log(\text{speed})$). Extensive noise measurements taken by the French National Railroad (SNCF) over a wide range of speeds show that wheel/rail noise dominates the A-weighted sound level from TGV trains at speeds up to 190 mph. The older TGV Orange train sets have higher levels of wheel/rail noise because of tread brakes that tend to roughen the wheel running surfaces and add to the noise. The newer TGV-A trains have tread brakes only on the power cars.

L_{dn}

Figure 4-1. Typical L_{dn} Levels.

Figure 4-2. Noise Sources on an Electromagnetic Maglev System.

Figure 4-3. Noise Sources on an Electrodynamic Maglev System.

Figure 4-4. Noise Sources on a Conventional High Speed Train.

Guideway Vibrations and Vehicle Body Vibrations.

Both of these mechanical sources tend to radiate sounds at very low acoustical frequencies. Fundamental resonance frequencies of guideway support beams are generally below 10 Hz, with radiation from box beam panels up to about 80 Hz. Vehicle body vibrations depend on the details of skin and body panel construction, but they can result in significant sound radiation throughout the audible range.

Maglev technology is not free from mechanical/structural sources despite the lack of physical contact with the guideway. The Maglev analogies to wheel/rail noise from a conventional train are:

- Noise from wheels rolling on guideway support surfaces at low speeds for electrodynamic levitated systems (this type of Maglev requires forward motion before lift can occur); and
- Noise from magnetic pole passing.

Moreover, since the guideway structure supports the Maglev vehicle, it is subject to similar dynamic loading forces as a conventional train, leading to similar vibrations and radiated sound from the guideway. The vehicle body constructions may also be similar to conventional train cars in response to dynamic forces, resulting in similar vibration and sound radiation characteristics.

Airflow Noise Sources

Noise from airflow over a train or Maglev vehicle is generated by:

- Flow separation and reattachment at the front;
- Turbulent boundary layer over the entire surface of the train;
- Flow interactions with edges and appendages; and
- Flow interactions between moving and stationary components of the system.

Airflow-generated, or aero-acoustic, sources result in increases in noise ranging from 50 to 80 times the logarithm of train speed and generally dominate noise levels from high speed trains at speeds of 150 mph or greater, depending on the significance of the mechanical/structural noise. Aero-acoustic sources generally radiate sound in the frequency range of 250 Hz to 500 Hz.

These sources can be located over the entire surface of the train and at the edges of guideway structure. Due to their relatively high placement on the vehicle (the top of the windshield is 12 feet above rail) and low frequency, sound barriers are less effective for aero-acoustic sources than for wheel/rail noise. Successfully reducing aero-acoustic noise generally requires high sound barrier walls.

All the foregoing sources combine in the sound signature of a passing train. One measure of the noise characteristics of a train is the maximum sound level in dBA. Figure 4-5 shows the maximum sound level (L_{max}) of representative high speed ground transportation systems in operation or under testing conditions.

Figure 4-5. Maximum Levels for High Speed Ground Transportation Systems.

Path of Airborne Sound

The path of sound from trains into nearby buildings remains fairly close to the ground. Reductions of sound level occur along the path from:

- Geometrical spreading as distance increases;
- Ground effects; and
- Attenuation as sound waves encounter building walls.

Atmospheric effects — such as wind direction and speed, wind gradient and temperature gradient — have temporary effects that change daily as the weather changes. These effects are not included in our projections for average conditions.

Noise can interrupt ongoing activities and can result in interference with noise-sensitive work. In this general analysis we assume that only noise sensitive land use (i.e., residential) would be affected by the project.

Ground-Borne Vibration and Noise

The basic concepts of ground-borne vibration are illustrated for a rail system in Figure 4-6. The train wheels rolling on the rails create vibration energy that is transmitted through the track support system into the ground. The amount of energy that is transmitted into the ground strongly depends on factors such as wheel and rail smoothness and the resonance frequencies of the vehicle suspension system and the track support system. Factors such as high speed, stiff primary suspensions on the vehicle, stiff track support systems, jointed rail, worn or flat wheels, or worn rail will increase vibration energy transmitted into the ground.

From the track support system, the vibration energy propagates through the intervening ground to the foundations of nearby buildings. Geologic factors strongly influence the levels of ground-borne vibration, though it is extremely difficult to predict accurately the effect unique soil conditions will have on propagation of ground-borne vibration. Among the most important geologic factors are stiffness and internal damping of the soil and depth of bedrock. Experience with ground-borne vibration indicates that propagation is more efficient in stiff clay soils, and shallow rock seems

to concentrate the vibration energy close to the surface and can result in ground-borne vibration problems at large distances from the track. Factors such as layering of the soil and depth to water table are expected to have significant effects on the propagation of ground-borne vibration.

Once vibration waves reach a building foundation, the vibration propagates into the foundation and throughout the building. The receiving building is a key component in projections, since ground-borne vibration problems occur almost exclusively inside buildings. The train vibration may be perceptible to people who are outdoors, but it is very rare for outdoor vibration to cause complaints. The vibration levels inside a building are dependent on the vibration energy that reaches the building foundation, the coupling of the building foundation to the soil, and the propagation of the vibration through the building. The general guideline is that the heavier a building is the lower the response will be to the incident vibration energy.

Figure 4-6. Ground-Borne Vibration Sources and Propagation Paths.

Ground-borne noise is the sound radiated by the vibration of floors, walls, and ceilings of rooms. The level of noise created by the vibration of the floors, walls, and ceilings depends on the frequency content of the vibration and the acoustical absorption of the receiving room. The more acoustical absorption in the room, the lower the noise level will be. For a room with average acoustical absorption, the sound pressure level is approximately equal to the average vibration velocity level of the room surfaces.

Noise/Vibration Impact Assessment Method

When introducing a new noise source to a pre-existing noise corridor, as in the case of the Conrail/Amtrak and NYS Thruway alignments, it is necessary to:

- Examine both the existing and projected noise and vibration conditions; and
- Establish criteria upon which to base evaluations of potential noise and vibration impact.

Appendix 4 at the end of this report includes descriptions of the methodology used to analyze the existing noise/vibration environment, model TGV and Maglev noise and vibration, and assess the extent of impact over each of the alignments for various TGV/Maglev speed profiles.

SUMMARY OF NOISE CRITERIA FOR HSGT

Impact Criteria

The noise impact criteria for HSGT operations are shown graphically in Figure 4-8. These criteria are based on comparison of existing noise levels and future noise levels predicted for the HSGT operations and characteristics of the specific technology. They are identical to those proposed by the Federal Transit Administration in the draft Guidance Manual for Transit Studies for assessing noise impact from urban transit operations, with the single difference that the "onset-rate adjusted Ldn" is used for high speed operations.

The noise impact criteria are defined by two curves that allow increase project noise levels as ambient noise increases up to a point, beyond which impact is based on the project noise alone.

There is considerable evidence that an adjustment is required for sound signatures with rapid onset rates (common to high speed systems). An adjustment of 5 dB to the sound exposure level is assumed for HSGT systems. The effect of this rapid onset adjustment is shown in Figure 4-7.

The noise criteria and descriptors depend on land use, designated either Category 1, Category 2, or Category 3.

- **Category 1** includes tracts of land where quiet is an essential element in their intended purpose, such as nationally significant historic sites or outdoor concert pavilions;
- **Category 2** includes residences and buildings where people sleep; and
- **Category 3** includes institutional land uses with primarily daytime and evening use such as schools, churches and active parks.

For Category 2 land use where nighttime sensitivity is a factor, the noise criteria use L_{dn} . For Category 1 and 3 land uses involving primarily daytime activities, the impact is evaluated in terms of the L_{eq} for the noisiest hour of transit-related activity during which human activities occur at a noise-sensitive location, which is referred to as "peak hour L_{eq} ."

The ambient noise and daytime peak-hour L_{eq} have similar values for typical noise environments. Therefore, they are used interchangeably to evaluate noise impact for Category 1 and Category 2 sites. The criteria allow the high speed ground transportation noise to be 5 decibels greater for Category 3 sites than for Category 1 and Category 2 sites, however, because the Category 3 sites are less sensitive.

The noise impact criteria are defined by two curves that allow increasing project noise levels as ambient noise increases up to a point, beyond which impact is determined based on project noise alone.

Below the lower curve in Figure 4-8, a transportation system is considered to have no noise impact since, on the average, the introduction of the system will result in an insignificant increase in the number of people highly annoyed by the new noise.

Figure 4-7. Speed/Distance Relationship Adjustment for Startle from Maglev Noise.

Figure 4-8. Noise Impact Criteria for HSGT.

The curve defining the onset of noise impact stops increasing at 65 Db for Category 1 and 2 land use, a standard limit for an acceptable living environment defined by a number of Federal agencies.

- High speed transportation noise above the upper curve is considered to cause severe impact since a significant percentage of people would be highly annoyed by the new noise. This curve flattens out at 75 dB for Category 1 and 2 land use, a level associated with an unacceptable living environment.

As indicated by the right-hand scale on Figure 4-8, the project noise criteria are 5 decibels higher for Category 3 land use.

Between the two curves the proposed project is judged to have an impact, though not severe. The change in the cumulative noise level is noticeable to most people, but may not be sufficient to cause strong, adverse reactions from the community. In this transitional area, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation, such as:

- The predicted level of increase over existing noise levels ; and
- The types and numbers of noise-sensitive land uses affected. Vibration criterion requires that for infrequent events (less than 70 per day) vibration levels should not exceed 80 dB for residential land uses and 83 dB for institutional/daytime land uses to avoid vibration impact.

Estimation Procedure Assumptions

An estimation procedure was used which assumed that the ambient noise is established by existing traffic, rail and motor vehicle, in their respective corridors. For both the Conrail/Amtrak/Metro-North and NYS Thruway alignments, the following assumptions were made:

- Amtrak trains consist of one 56-foot locomotive and six 85-foot cars and travel at the maximum speed allowed on the given track segment;
- Freight trains consist of one 56-foot locomotive and one hundred 60-foot cars and travel, on average, a maximum speed of 40 mph in sensitive land use areas; and

- Metro-North commuter trains consist of six 85-foot self-powered cars and travel at a maximum speed of 80 mph.

The number of daily traffic (rail and Thruway) operations is evenly distributed throughout a 24-hour day.

The total freight train operations for any given track segment was the difference between the total daily rail operations and Amtrak operations (or Amtrak and commuter operations along Metro-North).

Existing traffic, rail and NYS Thruway, dominate the noise environment in their respective corridors, except where the proposed high speed ground transportation vehicle deviates from the existing alignment.

Where the proposed high speed ground transportation deviates from the existing alignment, ambient noise is assigned based on land use according to relationships established by the US. Environmental Protection Agency.

Ambient noise is constant within the corridor and assumes the value of the ambient noise level (L_{dn}) estimated at 200 feet from the centerline of the existing source (track or roadway).

- The nearest residential building is at least 50 feet from the centerline;
- Thruway traffic volume is based on 1991 data provided by the New York State Thruway Authority;
- Daytime/nighttime traffic volume and percentage of automobiles, medium trucks, and heavy trucks operating on the Thruway are based on Tappan Zee Bridge toll plaza statistics for the alignment segment from New York City to Albany, and Buffalo city line toll plaza statistics for the alignment segment from Albany to Buffalo; and
- Daytime and nighttime traffic volume is based on an average daytime and nighttime traffic hour, respectively.

Noise impact is based on both project noise levels and ambient noise, an evaluation of existing noise conditions. Therefore, it is necessary to assess impact for the proposed Conrail/Amtrak/Metro-North and NYS Thruway alignments. The ambient noise near the project is usually determined through an estimation procedure that is based on noise measurements at representative locations in the study area. A field measurement program was not warranted, however, due to the extensive study area of this project, combined with the preliminary nature of the study.

The foregoing assumptions are used in rail and highway noise prediction procedures to determine L_{dn} at 200 feet from the center of the corridor.

Rail Noise Prediction

For each track segment of the Conrail/Amtrak/Metro-North alignment, the prediction model uses train speed and number of daytime and nighttime trains currently operating on the existing rail corridor to calculate ambient noise L_{dn} at 200 feet. The model considers Amtrak, commuter, and freight trains separately, calculating an L_{dn} for each train type present on a given segment, and adding them to yield the overall existing day-night equivalent levels at 200 feet.

Highway Noise Prediction

The highway noise prediction model uses hourly volume and average speeds for automobiles, medium trucks, and heavy trucks at each roadway segment to predict a one hour L_{eq} at 200 ft. By adding 24 one-hour L_{eqs} , weighting the L_{eqs} during the nighttime hours by 10 dB, the model calculates the existing ambient noise (L_{dn}) at 200 feet for a day at the given milepost segment.

This information for ambient noise due to the existing Conrail/Amtrak/Metro-North and NYS Thruway corridors is included in Table 4B-1 of the Appendix. Where the high speed ground transportation departs from the existing railroad/highway corridor, the ambient noise is estimated based on the land use according to relationships established by the U.S. Environmental Protection Agency. These relationships are shown in Table 4-4. The assumption that the traffic levels are uniform through the day on the New York State Thruway is a conservative assumption and may overstate the noise impacts.

Table 4-4. Estimated Land Uses and Corresponding Population Density in Areas with Various Day-Night Noise Levels.*

Description	Typical Range L_{dn} (dB)	Average L_{dn} (dB)	Average Census Tract Population Density, Number of People per Square Mile
Quiet Suburban Residential	48-52	50	630
Normal Suburban Residential	53-57	55	2,000
Urban Residential	58-62	60	6,300
Noisy Urban Residential	63-67	65	20,000
Very Noisy Urban Residential	68-72	70	63,000

*U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," EPA Report Number 550/9-74-004, March 1974.

PROJECTED NOISE AND VIBRATION CONDITIONS IN STUDY AREA

High Speed Rail Noise

The prediction model for noise resulting from the introduction of TGV-equivalent operations on the existing Conrail/Amtrak/Metro-North alignment was constructed based on data from the French National Railways, described in Internoise '90 proceedings (pages 371-374). The following operational assumptions were made for the proposed New York State VHSR system:

- Each VHSR train consists of two locomotives and six coach cars (includes four trailers and two transition vehicles); and
- VHSR operations for one 24-hour day consist of 18 daytime and 3 nighttime trains in each direction.

Source levels at reference distances were the basis for the final L_{dn} calculations. The source levels for VHSR are provided in Appendix 4.

High Speed Rail Vibrations

Freight trains are likely to dominate the existing ambient vibration conditions. Therefore, a model was established to compare freight train vibration with VHSR vibration. To evaluate the potential for ground-borne vibration and noise, the following assumptions were made:

- Average speed of existing freight trains is 40 mph;
- Projected maximum speed of freight trains is 79 mph; and
- VHSR (TGV-A) trains travel at a maximum speed of 200 mph.

The projections for VHSR vibration were based on measurements taken by Harris Miller Miller & Hanson, Inc. The vibration criteria for infrequent events (less than 70 per day) require that vibration velocity levels reach or exceed 80 dB for residential areas or 83 dB for institutional/daytime land uses in order for impact to occur. Figure 4-9 shows root-mean square (rms) vibration velocity level as it varies with distance for freight trains at average and maximum speed, and the VHSR at 200 mph. As shown by the three curves and the indicated criteria levels:

- The VHSR will have no vibration impact for distances greater than 50 feet from the center of the corridor;
- Within 50 feet, impact may occur in places where the TGV is traveling at 200 mph and freight trains speeds do not exceed 40 mph; and
- Where freight trains run at speeds ranging from 40 mph to 79 mph, however, vibrations from existing freight trains exceed those resulting from the VHSR.

Consequently, the introduction of new VHSR service is not expected to cause vibration impact.

Relative Noise Impact Areas

The linear extent of the noise impact is reported because it represents a measure of the extent of potential noise problems associated with a rail or Maglev transportation system. Mitigation

measures are prescribed for one or both sides of the ROW after a more detailed study is undertaken. The lengths shown here represent upper bound estimates of the route miles where such an investigation will be focused.

In areas where "impact" is identified, people may notice and be annoyed by the introduction of the new noise source, although a number of Federal agencies consider these noise levels to be within acceptable living conditions. Where "severe impact" occurs, a significant percentage of people would be highly annoyed by the new noise, and mitigation should be provided.

These results, along with a tabulation of the number of square miles affected by noise levels resulting from passing VHSR or Maglev vehicles, can be found in Table 4A-1 of the Appendix.

Table 4-5. Summary of Noise Impact from VHSR and Maglev.

VHSR - Alignment Impact from Noise and Vibration	Non-disruptive TPC-3	Aggressive TPC-5
Length of Impact Corridor (miles)	55.0	62.2
Length of Greater Impact Corridor (miles)	3.7	8.1
Maglev - Alignment Impact from Noise and Vibration	Non- disruptive TPC-4	Aggressive TPC-6
Length of Impact Corridor (miles)	99.9	116.7
Length of Greater Impact Corridor (miles)	45.9	69.5

The first line of noise reduction could be made in the design considerations of the vehicle and guideway. Noise levels can be lowered by as much as 5 dB through the design process. Of the noise mitigation techniques described in previous sections, noise barriers are usually the first to be implemented, and will provide at least a 5 dB reduction in the noise levels. Installation of noise barriers everywhere "impact" or "greater impact" is identified will decrease the linear extent of impact to 3.74 miles for TPC-3 and 8.1 miles for TPC-5 along the VHSR alignment, and 45.9 miles for TPC-4 and 69.5 miles for TPC-6 along the Maglev alignment. The mileage could be reduced along the Thruway by taking into account the noise levels during peak traffic flow.

NOISE AND VIBRATION MITIGATION MEASURES

For projects where noise and vibration impacts are anticipated, mitigation measures are available to reduce sound levels and vibrations. In the following section, possible alternatives to alleviate noise and/or vibration impacts are described.

Sound Walls

The favored mitigation for noise impact is to introduce a screen between the noise source and nearby receivers. A noise barrier built along the edge of the right of way, as close as possible to the source, can provide a noticeable noise reduction of 5 dB or more for both Maglev and VHSR systems. Mitigation was considered for receivers in both the "impact" and "severe impact" corridors.

For the proposed VHSR:

- The length of noise barriers required to mitigate noise in the impact corridor of is 55.0 route miles for TPC-3 (moderate) and 62.2 route miles for TPC-5 (aggressive); and
- The length required to mitigate noise in the severe impact corridor is only 3.7 route miles for TPC-3 and 8.1 route miles for TPC-5.

For the proposed Maglev system:

- The length of noise barriers required to mitigate noise in the impact corridor is 99.9 route miles for TPC-4 (moderate) and 116.7 route miles for TPC-6 (aggressive); and
- The length required to mitigate noise in the severe impact corridor is 45.9 route miles for TPC-4 and 69.5 route miles for TPC-6.

The assumptions used in the noise analysis were conservative and may overstate the noises levels somewhat. The analyses assumed a constant traffic volume as the ambient conditions on the Thruway. In reality, there are peak hours which would result in higher ambient noise levels than assumed in our model. Despite the conservative assumptions the results of the analysis of noise and vibration associated with high speed ground transportation show that there is little potential for vibration impact, and some minor noise impacts.

Ground-Borne Vibration and Noise

The projections of ground-borne vibration and noise indicate little potential for problems along the proposed VHSR corridor. Ground-borne vibration from VHSR trains is not expected to exceed the commonly experienced vibrations from existing freight trains.

On the basis of available data, it appears unlikely that there will be more than occasional intrusion from ground-borne noise or vibration. If this is found to be a problem under further, more detailed analysis, mitigation measures can be applied to reduce the potential for intrusion. The measures applicable to this project include:

- **Ballast Mats:** A ballast mat consists of a rubber or other type of elastomer pad that is placed under the ballast stones. There are several manufacturers of ballast mat systems that have proven systems for subway applications where the mat is placed on the concrete invert. There is limited information about how effective ballast mats will be if they are placed directly on the subgrade of at-grade track. Ballast mats should be capable of reducing the vibration at the frequencies where the projections exceed the criteria. In general, ballast mats can provide 10 to 15 dB vibration attenuation at frequencies above about 30 Hz;
- **Gapless Frogs:** A "frog" is a device used in crossovers and turnouts at the point where the rails cross. There is a gap in a normal frog where the two rails meet. Wheel impacts at this gap significantly increase levels of ground-borne vibration. An approach to mitigating this vibration is to use special frogs with either spring loaded or movable points that close the gap on the main running rail and significantly reduce the vibration levels;
- **Building Vibration Isolation:** Constructing vibration isolation measures into new building foundations can be an effective approach for controlling ground-borne vibration and noise inside specific buildings; and
- **Speed Reductions:** Reducing speed to reduce vibration levels is sometimes the best approach. However, since ground-borne vibration is typically proportional to 20 log (speed), it usually takes a relatively large speed reduction to reduce vibration levels significantly.

Figure 4-9. Projected Vibration from TGV and Freight Trains.

ELECTROMAGNETIC FIELD (EMF) EFFECTS

The effects of electromagnetic fields upon human beings are not completely understood and claims of harm or safety remain controversial and inconclusive. Numerous research activities have been outlined by the Environmental Protection Agency and the Department of Transportation to provide additional evidence to assist in resolving the question of health effects and to assist in the development of guidelines for exposure limits and equipment shielding. Research on transit and intercity rail systems is in progress at this time. The operation of a high speed surface transportation system involving electricity or magnetic technology, such as a VHSR or Maglev system, would require the construction of either a catenary power supply or guideway-mounted electromagnets.

Source and Strength of Electromagnetic Fields Common to Our Environment

All electrically powered systems, including VHSR and common household electrical appliances, and all magnetic devices, including Maglev, generate EMF. The effects of long-term exposure, such as living near high-power transmission lines, or long-term exposure to certain appliances have caused the most public concern. Today there are no universally accepted regulatory standards for evaluating the level, character, or duration of exposure to EMF.

The background magnetic field level that exists in the typical American home ranges from 0.5 to 4.0 milli-gauss (mG).² Exposure levels vary as a function of type of source, the distance from the source, and the time or duration of exposure. Figure 4-10 shows the median field strength generated by common household appliances and the field reduction with distance.

Electronic Research Management, Inc., under contract to the FRA, has also reported measured magnetic field characteristics of conventional electric rail systems (Amtrak, Metro-North, New Jersey Transit, MBTA, Washington Metro, and trolley systems) and high-speed rail systems (the French TGV-A system). These systems generally produce exposures which are somewhat higher in intensity than the Maglev system but have a different frequency distribution. Conventional electric rail

² U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, *EMF In Your Environment: Magnetic Field Measurement of Everyday Electrical Devices*, (Washington, DC: U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, December 1992), 15, 402-R-92-C08.

systems, like the TR07 Maglev, show high spatial and temporal variability (depending on train speed, etc.) and expose passengers and crew to "spikes" of fairly high exposure. Unlike the Maglev however, the frequency range is generally more narrow, centering on the power frequency (e.g., 25 or 60 Hz for AC systems) and its odd harmonics. DC-powered systems have a large DC component with some extremely low frequency components resulting mainly from ripples in the rectification electronics.³

Figure 4-10. Electromagnetic Field Generation.

³ An Overview of Biological Effects and Mechanisms Relevant to EMF Exposures from Mass Transit and Electric Rail, DOT/FRA/ORD - 93/32.

VHSR

Although EMF exposure is expected to be minimal due to the relatively low power levels needed to operate an electric VHSR system (relative to existing high-voltage and distribution lines within urban areas), the presence of catenary lines may create public concern. Electric power requirements for train operation range from 15 kV, 16-2/3 Hz used to power the Swedish X-2000 tilt trains to 25 kV, 50 and 60 Hz to power the Japanese *Shinkansen* and French TGV vehicles, representing voltages that are lower than those associated with existing American power distribution systems and high-voltage transmission facilities.

Maglev

Maglev systems are powered using a series of conventional or superconducting electromagnets located in the guideway; and energized at the moment when the train passes. The field strength generated by superconducting magnets generally are higher than those generated by conventional electromagnets. The field strengths and thus exposure levels can be mitigated somewhat with the use of proper shielding and component and system design.

Research conducted by the Canadian Institute of Guided Ground Transport concluded that magnetic field levels within the cabin of the German Transrapid Maglev vehicle were not strong enough to harm either human beings or sensitive equipment such as a wristwatch or heart pacemaker (Vranich 1991). Smith (1990), however, states that "superconducting magnets such as those used on the Japanese system, may present hazards that will require special design or shielding to minimize effects on human physiology and biomechanical devices such as pacemakers."

While clearly a Maglev system will produce EMF, it is still not known what, if any, effects these fields would have on the system's passengers or workers. In the first Japanese demonstration Maglev system, superconducting magnets with high-flux densities were used, resulting in strong dc magnetic fields in the cabin (up to 350 gauss) without appropriate shielding. However, current designs, incorporating shielding, have achieved a reduction in cabin level exposure to below 10 gauss, and with additional shielding and magnet design modifications it would be expected to fall within or below current safety guidelines for workers and passengers alike.⁴

⁴ U.S. Congress, Office of Technology Assessment, *New Ways: Tiltrotor Aircraft and Magnetically Levitated Vehicles*, (Washington, DC: U.S. Government Printing Office, October 1991), 45, OTA-SET-507.

Potential Health Risks Associated with Electromagnetic Fields.

Possible adverse health effects associated with exposure to EMF have been a controversial issue for more than twenty years, and research has been conducted to establish a link between exposure and an increased incidence of a variety of health disorders. Potential adverse health effects resulting from EMF exposure first gained widespread public visibility in 1979 when an epidemiological study suggested a link between exposure to EMF (generated by some residential wiring configurations) and an increased incidence of childhood leukemia (Wertheimer and Leeper 1979). Other studies supporting possible EMF-health linkages were conducted by Tomenius (1986) and Milham (1983). Conversely, studies conducted by Fulton *et al.* (1980), Coleman *et al.* (1989), and others indicate that linkages can not be established statistically. To date, cause-effect relationships have not been established. The Environmental Protection Agency continues investigation into the matter, but conclusions have not been made.

Recent epidemiological studies have shown a potential link between prolonged exposure to 60 Hz fields and cancer, but the evidence for potential health risks from low-level exposure is inconclusive. Intense public concern has had an impact on such diverse technologies as electric transmission lines and computer monitors concerning EMF and protection against EMF. The topic of potential health risks associated with electromagnetic fields is controversial because the available evidence suggests a complex and nonlinear exposure response relationship. Low frequency (50 to 200 Hz) magnetic fields may be the most problematic. Several epidemiological studies have indicated that long-term exposure to ranges from as large as 50 to 60 Hz fields to as small as 250 microteslas in strength is correlated with an increase in cancer rates.

Electromagnetic Field Standards

The effects of EMF are related to the emission levels, the duration of exposure, and one's distance from the source. The Volpe National Transportation System Center currently is investigating the EMF associated with non-electric and electrified rail systems as well as Maglev. Field strengths are measured as a function of time, direction, and distance above the floor for different frequencies. It has only recently been possible to record and store all the discrete segments of the frequency bands that according to biological reports may be important.

EMF measurements on the TGV and in the Transrapid vehicle, near the guideway, in the passenger station, and near the power supply equipment (inverter building, transformer yard, feeder cables) focused on the frequency bands from dc fields or zero to 2000 Hz.

The time-varying magnetic fields in the passenger compartments of the TR07 vehicle covered the frequency range from 2.5 Hz to over 2 kHz and were highly variable over time. The average field levels ranged from approximately 100 mG near the floor of the vehicle to approximately 20 mG at standing head level. Typically, 70 to 80 percent of the time-varying magnetic fields were at frequencies below 47.5 Hz. The magnetic fields of magnitudes found in the passenger compartment of the TR07 can be shown to fall well within the intensity levels that characterize magnetic fields found near the edge of transmission line rights-of-way and near household appliances.

Exposure near the Maglev guideway should be lower than near existing electrified rail rights-of-way because the guideway sections would be powered in blocks as the trains pass, eliminating the continuous power distribution along the full length of the system characteristic of electrified railroads.

There are efforts currently underway to set safety standards for acceptable electromagnetic field levels. The International Radiation Protection Association (IRPA) has set 100 microteslas (1 gauss) as the limit for maximum ac field exposure. For occupational exposure to a low-frequency magnetic field, a 5-gauss limit or 500 microteslas is assumed to be the maximum exposure levels for an eight-hour workday. This limit was based on threshold interference with heart pacemakers rather than on biological effects, due to a better understanding of effects on electrical components than on the human body. Currently, acceptable low-level magnetic field levels associated with Maglev systems range from one to 100 microteslas (0.01 to 1.0 gauss).

In September 1990, the Public Service Commission adopted an interim policy to limit magnetic fields to 200 mG at the edge of future major electric transmission line rights-of-way (for all 345 kV circuits). The Commission made it clear that this was not a health-based standard, but rather pursuant to a policy of prudent avoidance. In addition to this standard, in 1978, the Commission adopted an interim electric field limit of 1.6 kV/m at the edges of future transmission line rights-of-way.⁶

⁶ State of New York Public Service Commission, "Statement of Interim Policy on Magnetic Fields of Major Electric Transmission Facilities," September, 1990, State of New York Department of Public Service, "Procedural History," January 11, 1988.

LAND USE AND DEVELOPMENT GROWTH MANAGEMENT

Land use and transportation are inextricably related, but the exact nature of that relationship is highly dependent on the specific transportation technology, the inherent characteristics of the neighboring land, and a host of public policies which indirectly and directly affect this relationship. In the United States, there is a long tradition of separating policies regarding the two issues: land use historically has been regulated by the state through local jurisdictions and transportation has been directed more by federal policy through interstate commerce regulation.

The relationship between transportation technology and urban form is inexact, but historical examples of streetcar suburbs and interstate industrial parks serve to demonstrate the existence of some correlation. These examples suggest that the development of innovative transportation infrastructure can lead to the expansion and development of new land uses to take advantage of time savings and other economic conveniences of any new transportation resource. During the last 50 years, most North American cities have decentralized dramatically, due to several factors, including the explosive growth in automobile use, the transformation from a manufacturing-oriented to a service-oriented economy, the widespread ownership of single-family houses, and the general rise in living standards and personal income. The negative aspects of decentralization, or "sprawl," including inefficiencies in land use and energy consumption, increased traffic congestion, deteriorated air quality, and weakened social community structures, have lead to a renewed discussion of using transportation development to influence land-use development. The expansion of "edge cities" has changed the focus of the demand for transportation monies toward suburban traffic corridors development.

The potential development of a HSGT system in New York State, with stations in the historic centers of the State's largest cities, could serve to replace some commercial and social focus on those urban centers, away from outlying suburban sites. While promoting a more efficient use of land and energy resources, the HSGT could retard the process of urban sprawl that has been encouraged by the location of transportation intermodal focus points, such as airports and highway interchanges, well outside city centers. Japanese and French examples of HSGT development suggest that transportation technology can be applied to effect change in land-use patterns and that

improved transportation technology can cause a more balanced modal distribution that, in turn, affects land-use patterns.⁷

Comparison of Technologies

The current pattern of land uses in New York State are not so different from patterns in many other parts of the country. The areas in towns immediately next to former railroad stations reflect older, centralized land development with mixed uses and contained community functions, while suburban areas immediately next to interchanges on the NYS Thruway generally reflect newer, decentralized land development characterized by sprawling complexes, more abundant parking, and single-use structures. A no-build strategy with little change in land-use regulation would likely mean a continuation of the existing patterns and trends away from the centralized model and towards the decentralized model.

Alternatively, a new HSGT system, *with adjustments in land-use regulation*, could mean substantial changes. An Incremental technology that leads to increased HSGT patronage and a decrease in automobile usage could slow the sprawling development of exurban areas. This assertion assumes a coordination of land-use planning and transportation efforts among state and local officials. A VHRS system developed with the same coordination of intergovernmental regulations could lead to a more pronounced shift in land-use patterns. The best examples in this country of this new development along intercity rail corridors might be Metropark, New Jersey and New Carrollton, Maryland, however these sites are also well served by highway access facilities. The limited development of VHRS in the United States has rendered few examples of true VHRS land development, however there are some examples in France and Japan.

There are two schools of thought on the effects of the development of a Maglev system upon land-use development although there are no large-scale commercial examples from which to develop models. One postulates that land surrounding Maglev stations will develop as does land around airports. This assertion assumes the location of Maglev stations in outlying, semi-rural areas where open land dominates. The other view holds that land around Maglev stations will develop similar to land around rail stations, and this view assumes Maglev station location in more urban areas. These

⁷ William Gimpel, "The Effects of High Speed Rail on Urban Decentralization," *High Speed Ground Transportation Systems I*, (New York, NY: American Society of Civil Engineers, 1993), 189.

two views assume parallel coordination of land-use regulation and they differ primarily on the assumption of Maglev system design and station location.

Land-Use Impacts

A survey of the types of land uses along the study area was made as part of the overall assessment of the existing conditions of the Empire Corridor and the NYS Thruway. Figure 4-11 shows the distribution and percentages of each type of land use. As might be expected, the rail corridor passes through more suburban and industrial areas than does the NYS Thruway corridor. These land-use patterns are important to the evaluation of the impacts of a new HSGT system.

In rural areas, land use impacts may be substantially less severe. However, the separation of communities or land uses must be carefully considered, especially if establishing an alignment that may diverge from the existing ROW which could interrupt existing surface transportation patterns or land uses. For example, access must be maintained to individual neighborhoods, emergency services, and commercial and employment centers.

Land-use impacts at new station locations could be substantial. These impacts can be both beneficial and adverse, and appropriate planning must be conducted to maximize benefits and minimize damages. When designing a VHSR or Maglev system within an existing transportation facility's ROW, sound barriers and shock absorbing devices or the placement of track/guideway on an elevated structure or in an underground tunnel are proven techniques for minimizing land impacts. But these measures have limitations. Tunneling is 10 to 25 times more costly than at-grade construction and can require reduced speeds, limiting its practical application to alleviate environmental impacts.

Interaction with Other Transportation Modes

Potential access to or interference with other transportation modes sharing the HSGT system's corridor would have variable impacts on the existing transportation systems between New York City and Buffalo/Niagara Falls. The most positive effect associated with the installation of a HSGT system would be the anticipated reduction in passenger cars on the state's highway network. Reduction in auto usage would help improve air quality, reduce energy consumption, and enhance overall transportation safety. Negative impacts could include competition for limited ROW space and station facility space wherever the HSGT would interface with conventional transit, commuter,

long-haul, and freight rail services. The potential for interaction of HSGT/Maglev with other transportation modes along the Thruway corridor would be great, especially if the system is placed at or near grade, as discussed above.

Figure 4-11. Adjacent Area Land Uses.

Interaction between the HSGT vehicles and motor vehicles using the Thruway could prove to be beneficial if all potential for intermodal efficiencies is realized. This is particularly true when considering the opportunities for the development of intermodal transfer facilities along the existing highway alignment, facilitating a decreased dependence on motor vehicles and concomitant decreases in highway congestion and environmental degradation.

Current train operations along the railroad alignment include Metro-North's Hudson Line that operates between New York City's Grand Central Terminal and Poughkeepsie, and Amtrak's Empire service that operates between New York City's Pennsylvania Station and Buffalo/Niagara Falls, Toronto, and Montreal by way of Albany. Conrail freight also operates within this corridor, usually in the evening after Metro-North and Amtrak suspend daily operations.

When examining potential conflicts associated with a VHSR system sharing ROW with existing passenger and freight rail alignments, a number of issues must be considered. One of the most pressing issues is availability of ROW. This is particularly true when examining the rail segment between New York City and Albany where the existing alignment follows the banks of the Hudson River.

It would be expected that a newly introduced VHSR or Maglev system would supplement existing long-haul passenger rail service throughout the state, and that conventional long-haul, commuter, and freight rail service would remain in operation. Any investigation that suggests track takings or current operating ROW infringement must recognize this and adjust for the maintenance of existing services.

Right-of-Way Impacts

The construction and operation of a HSGT system could result in several short-term and long-term environmental impacts. Right-of-way (ROW) acquisition would affect residents and businesses along the alignment and at station locations; and direct impacts could result from increased traffic levels on arterials serving the stations. Such impacts include potential degradation of visual aesthetics along ROW and at station locations, the introduction of HSGT-generated noise, and a possible degradation to water quality and habitat within local streams, rivers, and lakes.

Using existing highway or railroad ROW can reduce the cost of land acquisition and minimize the physical and environmental impacts normally resulting from the construction of a new transportation

system. This is particularly true for cross-state systems that may share interstate or regional rail ROW. To develop a HSGT system capable of performing at its optimum speed, it will be necessary to deviate from the existing highway or rail ROW to correct for speed limiting curves. The approach taken in this study was to maximize the use of the existing alignment ROW to the greatest extent possible but modifying groups of curves to improve speeds with minimal impact on adjacent lands. The typical ROW requirements of HSGT systems are shown in Table 4-6.

Table 4-6. Typical ROW Requirements of HSGT Systems.

Characteristic	VHSR	Maglev
Width of ROW	50 to 80 ft.	30 to 40 ft.
Elevation (typical)	At-grade	15 to 35 ft.
Horizontal Curve	13100	7350 *
Maximum Grade	4%	10%

* At comparable speed of 186 mph; larger radius required for higher speeds.

The alignments of the Empire (rail) Corridor and the NYS Thruway were documented in detail as part of the original existing conditions survey. These alignments originally were developed for a much slower maximum speed than those envisioned for VHSR and Maglev, and are constrained in segments by local physiographic features, particularly along the Hudson and Mohawk river valleys. The rail line has served as a primary feeder of passengers and freight into New York City and, as a result, development of residential, commercial, and industrial land uses has been concentrated along this corridor. These historic and topographic factors combine to challenge any effort to realign the tracks or ROW. While this is particularly true for the New York City metropolitan area, similar conditions exist around urban areas across the State.

The use of existing or former rail corridors along the study area may mitigate some of the environmental impacts of a new at-grade system. However, it is assumed that the VHSR will operate on fully dedicated track, and its implementation will require the construction of numerous new grade separations.

Construction of a HSGT system along the Thruway corridor would involve a higher degree of engineering complexity and safety considerations, as well as higher anticipated costs. If maximum

use of the Thruway ROW were assumed, the provision of suitable clearances for HSGT operations at overpasses and grade separations at roadway interchanges would increase costs. The straightening of curve sections would result in excursions from the ROW, limiting the practical use of the median, and the possible integration of crash barriers or other separation partitions would complicate ROW considerations.

The use of an elevated guideway configuration for HSGT provides flexibility in aligning the guideway while maximizing use of the Thruway ROW and providing safe clearance over motor vehicle traffic and reduces the impact on sensitive areas, such as wetlands. An elevated guideway may create varying shadow and light conditions on the roadway below, but vehicular sight distance can be maintained. At- or near-grade guideway sections are possible, but restrictions imposed by the very large vertical curve requirements limit their use along the Thruway. Some of the advantages and disadvantages of at-grade and elevated systems are summarized in Table 4-7.

Estimated New Land Area Requirements

An attempt was made to estimate the amount of new land necessary to realize the proposed HSGT systems. This exercise was done using limited cartographic information and using general assumptions about technology and application. This is a general estimate exercise, it is not precise and it is intended for the purposes of contrasting the different land needs of the technologies. For this exercise, no actual land measurements were made and no formal engineering estimates were applied to specific topography. General realignments were traced upon survey maps of the study area, ROW were corrected according to presumed curvature limitations, and geometric estimates were calculated for the areas of the land outside the existing ROW needed for the proposed ROW. While this method is not precise, as the same assumptions and practices were applied for both alignments, the exercise serves to contrast the relative land needs of the rail and Thruway scenarios for varying goals.

Estimates of the additional lands needed for curve corrections for the non-disruptive and aggressive realignments of the Thruway and rail ROW appear below in Tables 4-8 and 4-9. These estimates are based on average curve radius and average curve length calculations. County-wide land acquisition requirements in these tables are based on the proportion of curve changes in each county relative to the estimated number of curve changes throughout each proposed corridor. Should the project proceed to a preliminary engineering stage, a more detailed analysis of land area

requirements would be necessary to determine more exact ROW variations and consequent land acquisition needs.

Table 4-7. Comparison of At-grade and Elevated systems.

At-Grade System

Advantages	Disadvantages
Lower costs	Changing profile following terrain
Smaller visual envelope	More cuts and viaducts depending on vertical curve restrictions
Easier to shield	Increase number of grade separations required
	Potential for land parcel/community isolation/restricted access where alignment deviates from existing ROW.

Elevated System

Advantages	Disadvantages
Reduced isolation of land parcels	Noise Amplification
Small footprint (important in sensitive areas) and land acquisition	Larger envelope
Fully grade separated for safety and limited access	Shadows below structure
Restricted intrusion	Potential greater visual impact
Reduced number of crash barriers (costs)	
Greater flexibility in alignment	

SITE-SPECIFIC ISSUES

Wetlands

HSGT development will affect a wide range of natural resources along the proposed alignments. Direct impacts resulting from construction would include those to wetlands and riverine and open-water habitat. The corridors in question cross numerous river valleys that are subject to frequent flooding, geologically hazardous areas, some prime farmlands, forested lands, areas with historical and archeological significance, and recreation resource areas. A no-build strategy may not require the introduction of new rights-of-way and any consequent wetland impacts, but the reader is reminded that a no-build strategy may not represent an environmentally benign system. If the existing state network of transportation (primarily highway) continues on its historic pattern of expansion and development, the environmental costs incurred on existing (highway) corridors must be considered. Incremental expansion and development of the existing rail corridor will most likely result in little additional wetland incursion.

Construction and operation of a VHSR or Maglev system may cross some new wetlands or sensitive areas but these impacts are minimized by the construction of the system along existing rail and Thruway rights-of-way. Wherever possible, the proposed corridor would use existing transportation ROW, however, flexibility of selecting route alternatives may be limited by the corridor's linear geometry and other physical, economic, and political constraints.

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Table 4-8. Estimates of Land Takings on the Rail Corridors.

**CONRAIL/AMTRAK/METRO-NORTH REALIGNMENT
New York Pennsylvania Station to Niagara Falls**

County	TPC-3 Number of Curve Changes	TPC-3 Average Additional Area/Curve (square feet)	TPC-3 Area Required Total (square feet)	TPC-3 Area Required Total (acres)	Percentage of Total	TPC-5 Number of Curve Changes	TPC-5 Average Additional Area/Curve (square feet)	TPC-5 Area Required Total (square feet)	TPC-5 Area Required Total (acres)	Percentage of Total
New York	48		57,432	1.32	5.6	48		200,876	4.61	5.2
Bronx	5		5,983	0.14	0.6	5		20,925	0.48	0.5
Westchester	88		105,292	2.42	10.3	88		368,273	8.45	9.5
Putnam	27		32,306	0.74	3.1	25		104,623	2.40	2.7
Dutchess	121		144,777	3.32	14.1	137		573,335	13.16	14.7
Columbia	64		76,576	1.76	7.5	71		297,130	6.82	7.6
Rensselaer	14		16,751	0.38	1.6	14		58,589	1.35	1.5
Albany	19		22,734	0.52	2.2	17		71,144	1.63	1.8
Schenectady	30		35,895	0.82	3.5	30		125,548	2.88	3.2
Montgomery	53		111,275	2.55	10.8	127		531,486	12.20	13.6
Herkimer	43		51,450	1.18	5.0	39		163,212	3.75	4.2
Oneida	50		59,825	1.37	5.8	47		196,692	4.52	5.0
Madison	11		13,162	0.30	1.3	13		54,404	1.25	1.4
Onondaga	39		46,664	1.07	4.5	42		175,767	4.04	4.5
Cayuga	13		15,555	0.36	1.5	13		54,404	1.25	1.4
Wayne	70		83,755	1.92	8.2	83		347,349	7.97	8.9
Monroe	47		56,236	1.29	5.5	45		188,322	4.32	4.8
Genesee	19		22,734	0.52	2.2	23		96,253	2.21	2.5
Erie	34		40,681	0.93	4.0	35		146,472	3.36	3.8
Niagara	23		27,520	0.63	2.7	29		121,363	2.79	3.1
TOTAL	858	1,197	1,026,598	23.57	100.0	931	4,185	3,896,166	89.44	100.0

Original train performance calculation data list segments between mileposts where curvature begins or ends. Tangent sections have been deleted from calculation data, and average values have been found for typical curve segment lengths (L). Average values were found for degree of curvature (D), and (D) and (L) values were manipulated to find average curve external using the formula $\{[1/\cos(L \cdot D/200)] - 1\} \cdot [18,000/(\pi \cdot D)]$. For each of the proposed alignments, average curve length value were generated as follows: L1: $(L \cdot D)/D1$ and L2: $(L \cdot D)/D2$. These values, along with given proposed curvature values (D1) and (D2), were used to determine TPC-3 and TPC-5 external values. Differences in external values for each proposed scenario were used to determine average additional area required per curve change. The number of curve changes in each county was used with this average value to approximate average county area requirements. The county percentages reflect the proportion of curve changes in each county to the total number of curve changes for each proposed alignment.

Table 4-9. Estimates of Land Takings on the Thruway Corridor.

**NEW YORK STATE THRUWAY ALIGNMENT
New York Pennsylvania Station to Niagara Falls**

County	TPC-4 Number of Curve Changes	TPC-4 Average Additional Area/Curve (square feet)	TPC-4 Area Required Total (square feet)	TPC-4 Area Required Total (acres)	Percentage of Total	TPC-6 Number of Curve Changes	TPC-6 Average Additional Area/Curve (square feet)	TPC-6 Area Required Total (square feet)	TPC-6 Area Required Total (acres)	Percentage of Total
New York	51		1,042,526	23.93	11.8	44		2,739,663	62.89	11.3
Bronx	3		61,325	1.41	0.7	2		124,530	2.86	0.5
Westchester	34		695,018	15.96	7.9	28		1,743,422	40.02	7.2
Rockland	19		388,392	8.92	4.4	18		1,120,771	25.73	4.6
Orange	29		592,809	13.61	6.7	22		1,369,832	31.45	5.6
Ulster	44		899,435	20.65	10.2	33		2,054,747	47.17	8.5
Greene	26		531,484	12.20	6.0	20		1,245,301	28.59	5.1
Albany	19		388,392	8.92	4.4	17		1,058,506	24.30	4.4
Schenectady	14		286,184	6.57	3.2	14		871,711	20.01	3.6
Montgomery	23		470,159	10.79	5.3	21		1,307,566	30.02	5.4
Herkimer	14		286,184	6.57	3.2	16		996,241	22.87	4.1
Oneida	11		224,859	5.16	2.6	11		684,916	15.72	2.8
Madison	12		245,300	5.63	2.8	12		747,181	17.15	3.1
Onondaga	25		511,042	11.73	5.8	25		1,556,627	35.74	6.4
Cayuga	10		204,417	4.69	2.3	10		622,651	14.29	2.6
Seneca	13		265,742	6.10	3.0	13		809,446	18.58	3.3
Ontario	22		449,717	10.32	5.1	22		1,369,832	31.45	5.6
Monroe	16		327,067	7.51	3.7	16		996,241	22.87	4.1
Genesee	10		204,417	4.69	2.3	10		622,651	14.29	2.6
Erie	12		245,300	5.63	2.8	12		747,181	17.15	3.1
Niagara	24		490,601	11.26	5.6	24		1,494,362	34.31	6.2
TOTAL	431	20,442	8,810,370	202.26	100.0	390	62,265	24,283,377	557.47	100.0

Original train performance calculation data list segments between mileposts where curvature begins or ends. Tangent sections have been deleted from calculation data, and average values have been found for typical curve segment lengths (L). Average values were found for degree of curvature (D), and (D) and (L) values were manipulated to find average curve external using the formula $\{[1/\cos(L \cdot D/200)] - 1\} \cdot [18,000/(\pi \cdot D)]$. For each of the proposed alignments, average curve length values were generated as follows: L1: $(L \cdot D)/D1$ and L2: $(L \cdot D)/D2$. These values, along with given proposed curvature values (D1) and (D2), were used to determine TPC-4 and TPC-6 external values. Differences in external values for each proposed scenario were used to determine average additional area required per curve change. The number of curve changes in each county was used with this average value to approximate average county area requirements. The county percentages reflect the proportion of curve changes in each county to the total number of curve changes for each proposed alignment.

Table 4-10. Approximate Linear Extent of Wetlands Intersected by the NYS Thruway and the Empire Rail Corridor Assuming 1000-Foot Zone on Either Side of the Alignment.

Corridor Segment	Approximate Linear Footage NYS Thruway	Approximate Linear Footage Conrail/Amtrak
NYC to Northern Suburbs	3,200	N/A
Northern Suburbs to Albany	171,000	22,000
Albany to Niagara Falls	97,500	74,600

The estimates noted in Table 4-10 are based on the New York State Freshwater Wetlands Quadrangle sheets covering New York City to Niagara Falls. Maps are unavailable for the rail corridor in the vicinity of New York City.

Direct and indirect construction-related impacts could include placement of fill in wetlands, streams, and rivers to support the HSGT and proposed elevated structures, disturbance of buffer vegetation during grading and construction, and an increased potential for temporary runoff contamination from construction equipment and related activities. Long-term impacts could include changes in local drainage patterns to wetlands where the HSGT impedes surface flows from adequate uplands.

Mitigation

Wetland mitigation can be undertaken to alleviate the severity of impacts. The following mitigation measures are recommended to help offset the impacts of the proposed system:

- Use existing crossings wherever practicable;
- Use elevated structures at all water crossings;
- Incorporate retained fill sections to minimize the area extent of fill;
- Provide adequate temporary erosion and sedimentation control during HSGT construction to minimize degradation of downstream water quality;
- Hydroseed or otherwise stabilize all exposed soil surfaces as soon as possible following site grading to further minimize the potential for erosion and sedimentation to wetlands;
- Prior to site grading, clearly mark the limits of clearing and disturbance; heavy equipment should be restricted from the area outside this flagged disturbance zone;

- Water crossings should be constructed during the dry season, to minimize impacts to aquatic habitat;
- Directly affected wetland and buffer areas should be rehabilitated following construction with supplemental plantings of native vegetation; and
- If additional compensation is necessary to offset wetland impacts, one option would be to rehabilitate degraded wetlands elsewhere in the vicinity of the HSGT corridor.

The best overall approach for mitigating wetland impacts would be developed after the alignment is determined. The mitigation plan should incorporate a range of measures, including avoidance of impacts wherever feasible, rehabilitation of degraded wetlands where possible, and creation of new wetlands where appropriate. The mitigation plan must be developed in consultation with appropriate permitting and regulatory agencies.

VISUAL IMPACTS

There are two factors to consider with regard to visual impacts: those associated with the construction of a linear, elevated or at-grade system within an existing transportation corridor--its aesthetics and line of sight; and startle effect on drivers using the same ROW. The latter effect is not clearly understood completely and is a function of the approach angle, frequency, relative speed, and noise levels. Startle factors can be taken into account in assessing noise impacts. Construction and operation of the proposed HSGT systems require the creation of new trackage or guideways which would affect the visual aesthetics within the study area. The extent of the degradation would be dependent upon view shed and exposure, distance between the viewer and the system, and the subjective perception of the viewers.

Much of the HSGT study area lies within rural or ex-urban lands, including scenic river valleys and rolling hills, long-ago cleared of forest to support agricultural activities. Deciduous woodlands which dominate valley margins could provide some concealment of HSGT activities during late spring through fall. The greatest impacts are expected to occur along ROW located within valley floors cleared for agricultural activities and at river crossings. Visual impacts within urban areas will depend on alignment and grade separation decisions.

The visual impact along the proposed alignments is affected by various technological factors particular to the two technologies in discussion (VHSR vs. Maglev), construction design details (at-

grade, tunnel, or elevated structure), the level of development adjacent to the alignments, and the mitigation measures that are employed.

Visual Characteristics

A no-build strategy suggests little change to the study area's visual character, however the reader must consider consequential changes in existing transportation facilities and their visual character as they will be required to absorb any future increase in travel demand. As a consequence, expansion of highways to accommodate increased vehicular traffic demand will change the visual character of a highway corridor as new lanes are added. This may or may not be perceived as having a greater visual impact compared with a high capacity narrow, but elevated guideway. Overhead catenary systems on VHSR systems pose visual and physical barriers if constructed on a new ROW or existing non-electrify segments of the rail corridor.

An Incremental strategy also suggests little change in the study area's visual character as it assumes no electrification or significant ROW shifts. High speed rail, with its stitched catenary and support poles traditionally placed approximately 50 meters apart and terminating approximately 19 feet above the track, would be quite visible and shape the visual character of the corridor whether the track is at-grade, or on an embankment or viaduct. Even if the alignment were within a cut, the catenary and poles would change the visual character of the corridor.

A basic Maglev structure is the guideway. Maglev guideways generally are envisioned as elevated structures or near grade (15 to 35 feet above the ground). Low volume systems could operate on single guideways but increased service levels would require a more massive double guideway, requiring larger footprints and more superstructure. ROW widths vary from 15 feet to 20 feet for the single guideway to 40 to 60 feet for a double guideway assuming clearance for the full dimensions of the superstructure and operating envelope.

Design and environmental standards, along with conservation and preservation monitoring, will shape the development of any HSGT system. Subjective review and public attitudes concerning trade-offs between technological/transportation development and environmental aesthetics will shape this discussion and will be a part of the HSGT development process from conception through operation.

CORRIDOR-SPECIFIC ENVIRONMENTAL IMPACTS

This corridor-specific analysis addresses environmental conditions, within each of several subcorridors for all proposed alignments, which could become potential obstacles to implementation. Corridor-specific environmental impacts were examined and are presented below. Attention was given to impacts pertaining to several subcorridors (New York City, the northern New York City suburbs to Albany, and the Albany to Niagara Falls corridors), and considering various issues including possible private land takings, Thruway or Conrail/Amtrak/Metro-North ROW takings, park land takings or intrusions, localized traffic disruptions, delays and detours, and potential wetland intrusions are included.

New York City Corridor

Because of the urban demographics and intense development patterns in the New York City corridor, the potential for adverse impacts here would be the highest of the entire HSGT alignment. The introduction of a HSGT system would affect local residential properties, community facilities, cultural resources, and businesses, during construction and operation. These impacts include the following:

- Increased noise and vibration levels during the construction and operational phases of the project;
- Potential residential and business takings for realignment purposes;
- Potential construction-related roadway network impacts would occur, however, they would be very short-term in nature and would involve temporary capacity reductions, disruptions, or detours at some construction sites;
- It also would be expected that short-term construction related impacts also would take place on the Conrail/Amtrak/Metro-North alignment resulting in system-wide delays due to the limited number of signalized tracks and speed restrictions. These delays potentially could affect Amtrak, Metro-North, the Long Island Rail Road, and New Jersey Transit, as well as station operations at Pennsylvania Station and Grand Central Terminal;

- The Conrail/Amtrak/Metro-North railroad alignment is adjacent to park land between mileposts 7.0 and 11.31. Minimizing impacts to sensitive lands, parks, visual impacts and access must be considered in the project planning and engineering;
- The Thruway alignment is adjacent to a park between mileposts -7.17 - 5.06 and 42-44.85. Again, minimizing impacts to sensitive lands, parks, visual impacts and access must be considered in the project planning and engineering; and
- A new Hudson River Crossing would be required to provide access to a New York City Terminal.

New York City Suburbs to Albany--Conrail/Amtrak/Metro-North Corridor

The Conrail/Amtrak/Metro-North railroad alignment from the northern New York City suburbs to Albany at one time accommodated a total of four tracks, however, current operations run on a total of two tracks for most of the segment. The existing alignment of this segment is situated along the eastern bank of the Hudson River. The outline of the river bank in this region has a gentle meander with a series of long sweeping reverse curves. Along this corridor land use to the east of the Hudson is characterized by hilly terrain with high, steep slopes immediately adjacent to the river. Located at the base of these high hills the alignment follows the shoreline in a pattern which basically outlines the river's edge. In other areas the shoreline is characterized as wetlands and marshes where the alignment generally traverses the wetlands in the same type of river outline fashion, connecting the higher areas of the shoreline together. Because of topographic constraints the alignment has little room outside the existing ROW (approximately 66 feet) for any significant realignment opportunities without involving major environmental impacts that include: private land takings of residents and businesses, wetland intrusions, and local street disruptions and takings.

Two separate Train Performance Calculation (TPC) investigations for implementing a VHSR system along this corridor were undertaken. They include the moderate non-disruptive alignment (TPC-3) and the aggressive realignment (TPC-5). In TPC-3, higher average speeds are made possible by using the existing ROW as much as possible, and avoiding residential and other developed areas. In TPC-5, a more aggressive approach was applied to the existing alignment to achieve higher average speeds in order to meet the goal of shorter travel times. This realignment would potentially require approximately one mile of elevated structure above the Hudson River which would eliminate a series of short radius reverse curves as the railway enters Hudson City from the south. Another

realignment would be located near Glenclyffe and Garrison Townships in Putnam County, near milepost 49. This realignment would eliminate a number of reverse curves but would, however, encroach upon a monastery where both construction-related and operational noise and vibration levels could potentially have adverse impacts on daily monastery activities.

Hudson River Fisheries

The Hudson River estuaries are typically highly productive ecosystems, that provide important nursery grounds for fish. Nearly 200 species of fin fish have been identified in this environment. The New York State legislature has found the Hudson River estuary to be of state and national importance as a habitat for marine, anadromous, catadromous, riverine, and freshwater fish species. Modification of the existing rail alignment may interfere with recreational and commercial uses of these areas, and would require a detailed environmental impact assessment.

The New York State Coast Zone encompasses the entire Hudson River portion of the project area and extends inland for four miles on the west side of the river and for two miles on the east side of the river. As such, all alternatives would need to comply with Coastal Zone Management policies.

New York City Suburbs to Albany--Thruway Corridor

Between New York City and Albany, the Thruway alignment was modified in two steps to improve travel times. The non-aggressive realignment (TPC-4) improves some families of curves with minimal disruption to adjacent lands.

TPC-6, the aggressive re-alignment, would require a realignment near Ardonia Township in Ulster County. This realignment would eliminate reverse curves and would require multiple crossings of the Thruway which potentially could affect the visual character of the Thruway. Under both TPC alternatives significant ROW takings would be necessary to achieve 300 mph speeds.

Albany to Niagara Falls Conrail/Amtrak/Metro-North Corridor

Because of its relatively wide ROW, the alignment from Albany and Buffalo is promising for the placement of a VHSR system. The need for additional land and ROW taking is reduced in this segment, thus reducing potential project impacts and costs. The Conrail Niagara Branch, from east of downtown Buffalo to Niagara Falls, has a large number of constraints imposed by highways, local

roads, residential and commercial development, and a limited ROW width. The Buffalo area also presents difficulties with narrow ROW, highways and local roads, tunnel, bridge and building restrictions. These conditions are most severe in Tonawanda (10 miles north of the central business district (CBD). Both construction-related and operational-adverse impacts, such as noise and vibration, land takings, visual character and roadway network disruptions, would be expected to be the most severe within this area of the subcorridor.

In the Rochester CBD and vicinity there are many curves, limited ROW widths, residential and commercial developments, and adjacent highways and local roads that would create several engineering challenges to access a downtown station location.

The Conrail/Amtrak railroad alignment is adjacent to parks between mileposts (MP) 206.0 and 207.0 (Saint Johnsville City Park), MP 265.72 and 268.35 (the Old Erie Canal State Park in West Oneida), and near MP 360.05 in Fairport Township. Potential noise and vibration impacts, and safety concerns during both the construction and operational phases of the project here should be considered.

Albany to Niagara Falls Thruway Corridor

The proposed Thruway Maglev alignment would be located mostly within the Thruway ROW except from Buffalo to Niagara Falls where the proposed alignment would use the existing Conrail alignment. The proposed corridor would diverge from the rail ROW near the Town of Tonawanda. This six-mile segment would join the Thruway in Williamsville near the Buffalo airport allowing for a potential intermodal connection.

A HSGT system on the Thruway may be best located on the outer edge of one side of the roadway rather than in the highway median. This would allow realignment of curves without necessarily requiring the guideway to be elevated over portions of the roadway. It also would minimize construction impacts on overhead bridges and on the Thruway. However, limitations in mapping precision did not allow for a detailed identification of the number of guideway crossings over the Thruway or the exact portions of these crossings.

CONSTRUCTION-PHASE IMPACTS

In areas of narrow existing ROW, lane reductions may cause traffic delays similar to those imposed on highway repair or expansion projects. Disruptions would be short-term and may involve temporary capacity reductions, disruptions, or detours at some construction sites. It would be expected that these short-term impacts potentially would be worse on the Amtrak/Conrail alignment due to system-wide delays due to speed restrictions imposed on the construction segments and the limited number of signalized available tracks.

Elevated structures, such as the Maglev guideway systems, may be able to use gantries and cranes to build out from the recently erected segments to reduce disruption and to maintain use of the active ROW. However, earth works (cuts, fills, and foundation preparation for footing) will require ground level activity.

Noise and Vibration Impacts During Construction

One of the impacts associated with the development of a transportation project is the short-term effects of noise and dust from construction activities. As with any large project, the construction of major transportation facilities involves the use of machines and procedures which, in the past, have resulted in increased noise levels around the construction site. Control of noise levels during construction in sensitive areas would be imposed on the contractor through the use of mufflers on his equipment and the use of restricted construction hours.

One of the most effective methods of assuring controlled noise and minimum noise impacts is the inclusion of noise limit specifications in the construction contract documents. Recent construction projects of the Metropolitan Atlanta Rapid Transit Authority (MARTA), the New York City Transit Authority (NYCTA) and the Washington Metropolitan Area Rapid Transit Authority (WMATA) systems have included noise restrictions in their contract specifications. Criteria for construction noise and vibration control in a format appropriate for inclusion in construction contracts documents can be developed during the engineering phase. Specifications also would require the construction contractor to comply with state and local ordinances and regulations.

In general, federally-funded projects require a survey to identify sensitive uses or specialized land uses that would be affected by noise from construction related activities with specifications written into the construction document to mitigate adverse noise impacts. The Federal Transportation

Administration has not developed construction noise regulations but usually relies on the regulations of other agencies as guidelines to limit construction noise.

Air Quality Impacts During Construction

During construction, dust resulting from excavation and grading would contribute to concentrations of suspended particulate matter. Construction contractors would have to comply with state and local regulations requiring reasonable precautions be taken to avoid dust emissions. This may include applying water or dust suppressants during dry weather, and taking other measures to prevent the transport of dirt and dust from the construction area onto nearby roads. Fugitive dust impacts would be limited both in area and duration.

Construction equipment, material hauling, and construction activities can affect traffic flow in the area near a project, especially when construction on existing roads delays established traffic flows. If construction were to reduce significantly the average travel speeds throughout the overall study area, emissions from general traffic would increase.

Construction would require the use of heavy trucks and smaller equipment such as generators and compressors. These engines would emit pollutants that would contribute slightly to the degradation of local air quality, but emissions from existing traffic sources in the project area would likely exceed construction equipment emissions. If asphalt paving is used at stations and parking lots, hydrocarbon emissions from the hot asphalt would be released during paving.

Mitigation Measures

Mitigation measures can be woven into the planning and design stages of the project. Through an integrated approach, some impacts can be totally avoided with minor alignment shifts or with other planning and design deviations. Many others may be more efficiently addressed during appropriate phases, and many mitigation measures can be provided cost effectively.

Emissions from construction equipment and trucks can be reduced by using new and/or well maintained equipment. Avoiding prolonged periods of vehicle idling and engine-powered equipment also would reduce emissions. The trucking of materials to and from construction areas, and construction activities that would obstruct traffic could be controlled or scheduled to minimize traffic

congestion during peak travel times. This would minimize secondary air quality impacts caused by reduced travel speeds.

Dust produced by construction could be reduced by using a number of techniques. Areas of exposed soils such as storage areas and construction roadway could be sprayed with water or dust suppressants. Areas that might be exposed for prolonged periods could be paved, planted with vegetation ground cover, or covered with gravel. Soils carried out of the construction area by exiting trucks could be minimized by wheel washing and covering dusty truck loads. Finally, that soil that does escape the construction area on exiting vehicles could be reduced with an effective street-cleaning effort.

To ensure that an adequate level of mitigation measures is applied to overcome potential adverse impacts, the following approaches should be developed to create a mitigation program:

- Mitigation should be an on-going part of the project;
- Mitigation should be project-wide in scope;
- Mitigation should be comprehensive through the duration of the project. Many impacts can be considered collectively, and applicable mitigation measures can be standardized throughout the potential alignment, resulting in design efficiency and reduced costs. Because a number of impacts are expected to occur, measures should be designed to mitigate a wide range of impacts simultaneously.

As the need for a comprehensive and integrated mitigation program is apparent even at this level of detail, assurances must be made that the measures are cost-effective in order to be approved and funded as a part of the project's construction.

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Section 5

HSGT CONSTRUCTION COST ESTIMATES

SUMMARY

For the New York City to Niagara Falls route, the estimated capital cost of the Maglev system at \$16.5 billion is about 2.4 times more expensive than the VHSR system at \$6.9 billion. However, these costs are developed for fully mature operating systems of each technology which have different infrastructural requirements. For example, the Maglev system has off-line stations requiring more switches at each station while the VHSR and incremental options have on-line stations.

The estimated annual operating and maintenance costs of both systems are approximately the same with the Maglev cost at \$100 million and the VHSR cost at \$97 million.

These cost estimates are preliminary and do not include the costs of land for rights-of-way for either system. In the detailed planning phase, the current order-of- magnitude costs will be refined with the exact system's alignment when set and will include cost requirements for land agreements with operating railroads or other parties, detailed structural requirements and environmental mitigation.

Order of magnitude capital cost estimates were prepared for the New York State HSGT systems based on the construction criteria specified for very high speed steel-wheel-on-rail (VHSR) and Maglev technologies.

Experience with high speed rail costs in Europe, capital cost estimates for proposed steel-wheel and Maglev systems in the United States and the estimates for New York State illustrate that Maglev is more expensive on a cost-per-mile basis.

HSGT Construction Cost Estimates

The capital cost of the New York State VHSR system is based on construction costs in the United States to replicate the design criteria of the European systems. The cost estimate has been adjusted to reflect 4th Quarter 1992 construction costs in New York State.

The cost of improving the performance of the existing rail system to a level consistent with the incremental improvement travel times shown in this study has been estimated at \$1.5 to \$2 billion. However, a detailed cost estimate for the incremental rail improvement option was not developed as part of this study. The estimate is based on a significant body of earlier analysis and cost estimating by the New York State Department of Transportation which were reviewed, then escalated for inflation and additional improvements required to achieve higher speeds.

Phased implementation of incremental improvements could provide significant improvements in performance at proportionally lower cost. With modest improvement to signaling, grade crossings, and track, maximum speeds of 125 mph can be achieved in a number of segments in the existing rail corridor using conventional equipment with lightly more powerful locomotives. Reduction of travel time from the current eight-and-one-half hours to less than six hours could be achieved at a cost of approximately \$1 billion.

The performance of the combustion engine X-2000 technology described in this report should be considered the maximum technically feasible in the existing rail corridor. As described in other sections, a variety of regulatory and institutional barriers may prohibit implementation. Additional costs (estimated at \$1 billion) would be incurred in the procurement of the more powerful locomotives, tilt cars, further improvements to grade crossings, signaling, new track and crash barriers to separate freight and passenger operations.

The cost of freight related facilities has not been incorporated in the cost estimate for any of the options considered. For the purposes of this study, it has been assumed that freight handling and sorting facilities would be owned by or leased to freight carriers and forwarders and would not represent a capital cost expenditure to the HSGT operating entity. The same assumption, although potentially less realistic, has been made for any specialized rail or Maglev vehicle modifications require to provide efficient and expedited freight loading and unloading.

Capital cost of the Maglev system is based on an estimating model developed by Parsons Brinckerhoff for the National Maglev Initiative System Concept Design. The guideway design is based on a precast concrete central spine box girder that supports the track slab on "outriggers" spaced every 4.5 meters.

HSGT Construction Cost Estimates

This design concept provides a number of advantages and cost savings for elevated structures with the stiffness required for a Maglev system. The structure used is estimated to be lower in cost than other guideway designs proposed to date and a change in the design concept would result in higher capital costs.

The capital cost estimates for HSGT construction in New York State are based on data developed from 1:25,000 scale maps and preliminary design criteria for stations, structures, and ancillary facilities. These data are preliminary and for the steel-wheel system do not include ROW costs for the purchase or lease agreements with the operating railroads. An order-of-magnitude cost for the Maglev ROW was estimated with the assumption that ROW in or adjacent to the Interstate Highways would be provided at no cost to the system. The estimates do include costs for rolling stock that cannot be confirmed until actual orders are placed. These initial estimates do provide a basis for comparison between the steel-wheel and Maglev systems.

The costs were developed by pricing the components of individual work items. These component costs were then combined to develop unit costs for the construction elements. The unit costs were applied to the estimate of construction requirements to develop total systems costs. Based on the preliminary nature of the capital cost estimates, a contingency of 20 percent was added to the overall costs to allow for unforeseen expenditures. An additional allowance of 15 percent was applied to the capital cost including the contingency for design and management.

Major system capital cost items are:

- Sitework;
- Track structure;
- Railroad structures;
- Grade separation at road and rail crossings;
- Stations;
- Yard and shops;
- Maintenance-of-way facilities;
- Administration building(s);
- Traction power;
- Signals, communications, and train control; and
- Rolling stock.

HSGT Construction Cost Estimates

Details of the cost estimates for the VHSR and Maglev systems are shown in Table 5-1. The capital cost for the Maglev system is shown for the segments from New York City to Albany and Albany to Niagara Falls along with the cost of the total system.

Table 5-1. Capital cost breakdown of Maglev and VHSR systems.

	Maglev	Maglev	Maglev	VHSR
Cost Category	NYC to Albany	Albany to Niagara Falls	NYC to Niagara Falls	NYC to Niagara Falls
Mileage.	144 miles	276 miles	420 miles	464 miles
Capital Cost	\$4,573,663,550	\$7,376,342,200	\$11,950,005,750	\$5,028,428,644
Contingency - 20%	\$914,732,710	\$1,475,263,440	\$2,390,001,150	\$1,005,685,729
Subtotal	\$5,488,396,260	\$8,851,610,640	\$14,340,006,900	\$6,034,114,373
Design and Management - 15%	\$823,259,439	\$1,327,741,596	\$2,151,001,035	\$905,117,156
Total System Cost	\$6,311,655,699	\$10,179,352,236	\$16,491,007,935	\$6,939,231,529
Total System Cost/ Cost/mile w/o land	\$43,830,942	\$36,881,711	\$39,264,305	\$14,955,240
Estimated Land Costs (Note 1)	\$114,728,387	\$51,820,046	\$166,548,433	Note 1
Total System Cost Cost/mile with land	\$44,627,667	\$37,068,465	\$39,660,848	Note 1
Vehicles/Rolling Stock (Note 2)	\$172,800,000	\$86,400,000	\$259,200,000	\$326,400,000

Note 1: For the Maglev System, it is assumed that there is no cost for the ROW adjacent to the Interstate Thruways. No cost projection is available for the VHSR pending negotiations with the operating railroads for the lease or purchase of their ROW.

Note 2: The cost of the Maglev vehicles and the steel wheel rolling stock is included in the systems costs.

COMPARATIVE COSTS OF OTHER VHSR SYSTEMS

As noted earlier, the terrain of the HSGT route has a major impact on the capital costs. For example:

- On relatively flat terrain like the 200-mile Paris to Lille route in France, the projected cost of the 200 mile route including infrastructure requirements is \$14 million per mile ;
- The German high speed lines constructed over rough terrain with numerous bridges and tunnels cost an average of \$32 million per mile; and
- In Spain, the national railroad's 290-mile Seville to Madrid route is projected to cost \$9.7 million per mile. The relatively low Spanish cost is the result of having only 14 miles of viaduct and 6 miles of tunnel along the entire route.

The projected cost of an Ohio high speed rail system from Cleveland to Columbus to Cincinnati, when escalated for a direct comparison with New York State costs, is \$14.8 million per mile. This compares favorably with \$15 million per mile projected for New York State when you consider:

- The New York VHSR incorporates 135 miles of crash barriers at a cost of \$214 million – the Ohio system has no crash barriers;
- The New York system has 0.2 miles of tunnel at \$24 million – the Ohio system has no tunnels; and
- The New York system is fully-grade separated from roads and other railroads – the Ohio system has 103 road crossings and 16 railroad crossings at-grade that severely impact train speed, particularly in the urban areas between Columbus and Cincinnati.

This capital-cost comparison between a VHSR system in New York State and Ohio includes the 20 percent contingency and 15 percent design and management for both locations. Land costs are not included for either State.

COMPARATIVE COSTS OF OTHER MAGLEV SYSTEMS

The Maglev capital cost developed in this study includes estimates of the number and types of major structures required, 7 miles of tunnels and civil reconstruction costs. As shown in the matrix, the

HSGT Construction Cost Estimates

estimated capital cost of the New York State Maglev along the Thruway corridor is \$39.3 million per mile and includes all the infrastructure, vehicles, contingency, design and management costs. The cost of the 420 miles of guideway is \$16.8 million per mile.

Cost estimates for the Maglev technology vary widely. The following estimates do not include any allowance for special infrastructure, such as bridges and tunnels. If a route has extensive requirements for special infrastructure or is over rough terrain, the average cost per mile will escalate significantly.

- The German Transrapid system is estimated to cost \$20 million per mile with guideway cost comprising about \$15 million (not route specific);
- The Japanese HSST is projected to cost \$14 million per mile; and
- The Japanese MLU 001 technology under development is estimated to cost \$37 million per mile.

A number of feasibility studies for Maglev systems in the United States and Canada have been prepared with the cost estimates ranging from \$14 million to \$53 million per mile in 1991 dollars. The Philadelphia-Pittsburgh route was the most expensive due to the requirements for special infrastructure while the Montreal-Ottawa route was the least expensive.

The wide range in Maglev cost estimates is a result of the differing environments of the proposed corridors as well as the lack of practical experience in building Maglev systems for revenue service. Differences in costs also can be attributed to differences in local economic variables and potential inconsistencies in assumptions made by the estimators for the various systems.

Summary

Both the railroad and Thruway corridors have the potential to accommodate a high speed ground transportation system. Detailed engineering studies will have to be performed to improve the understanding of the VHSR and Maglev alignments and identify any restrictions not previously considered.

Several variations of the alignments were analyzed to determine what level of performance improvements could be achieved with varying degrees of change to the curves in each corridor. Running

HSGT Construction Cost Estimates

times between New York City and Niagara Falls have been calculated with trip times as low as approximately four hours for VHSR and two-and-one-half hours for Maglev.

VHSR rail travel times for the total corridor decreased by approximately 1.0 and 1.5 hours for the moderate and aggressive alignments, respectively. Corresponding time reductions for Maglev with alignment adjustments were about 20 and 30 minutes, respectively. Using a Maglev vehicle capable of tilting improved the travel time along the Thruway by approximately 20 minutes. Assuming a no-tilt Maglev vehicle on the non-disruptive alignment produced trip times comparable to those for a tilt Maglev on the existing alignment (i.e., no curve modifications).

Alternative station locations have been identified for each of the major metropolitan areas along the corridor to provide options relative in proximity to the CBD and/or interface with other transportation modes. Input from the local MPOs was solicited to coordinate the station siting recommendations with local planning. For New York City, alternative station locations using different approaches to the city are proposed at Pennsylvania Station, Sunnyside Yards, and Secaucus, NJ. Access into New York City is planned to follow the existing rail ROW recognizing that the train speed will be reduced in the urban area.

The capital cost for the VHSR technology is slightly under \$15 million per mile or \$7 billion total systems cost. Maglev capital costs are \$16.5 billion for a system from New York City to Niagara Falls or \$39.3 million per mile. The cost estimates for both technologies include a 20 percent contingency allowance and 15 percent design/management fee but do not include ROW acquisition costs. The advantage of the Maglev system is that the trip time between New York City and Niagara Falls is almost half the time required for the VHSR (steel-wheel) system.

The VHSR capital costs are summarized in Table 5-2.

Table 5-2. Summary of the VHSR Capital Cost Estimate.

ITEM	COST (1993 \$)
Right-of-Way	Not Estimated
Track and Structures	\$3,222,178,165
Electrification	999,522,955
Signals and Communications	363,998,340
Stations	58,628,228
Yards and Shops	57,700,866
Sub-total	\$4,702,028,644
Rolling Stock	\$ 326,400,000
Sub-total	\$5,028,428,644
Contingency - 20%	\$1,005,685,729
Sub-total	\$6,034,114,373
Design and Management	\$ 905,117,156
TOTAL CAPITAL COST	\$6,939,231,529

VHSR OPERATIONS AND MAINTENANCE COST ESTIMATE

General

The operations and maintenance costs are based on the cost experience for the European steel-wheel high speed rail systems and adjusted as appropriate, for the environment in the United States. Labor costs are based on the experience of passenger rail facilities in the United States. The alignment used for this analysis is the existing Conrail/Amtrak route with the high speed rail system grade-separated from roads and other railroads and when at-grade the route is physically separated from existing freight and passenger operations.

The alignment selection has a negligible impact on operations and maintenance costs.

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Operations and Maintenance Assumptions

Operations and maintenance costs are based on the following assumptions:

- Trains make 8 round trips between New York City to Niagara Falls on weekdays;
- Trains make 4 express round trips between New York City and Albany on weekdays;
- Trains make 4 round trips between New York City to Niagara Falls on weekends;
- Trains make 2 express round trips between New York City and Albany on weekends;
- Trains operated between New York City and Niagara Falls stop at all stations;
- Express trains operated between New York City and Albany do not stop at intermediate stations;
- The trains are electrified and capable of operating at a maximum speed of 200 mph;
- Each train has two power units, two first class coaches, four second class coaches, and a restaurant car. There are 48 seats in the first class cars and 76 seats in each custom coach. The seating capacity per train is 400 passengers; and
- The costs are in 1993 dollars for a mature system that has been operating for ten years; the operations and maintenance costs in the initial years of operation will be lower.

System Rolling Stock, Infrastructure, and Operations

The VHSR system rolling stock, infrastructure and operations are as follows:

- **Equipment -**

Number of train-sets	16
Power units per train	2
Passenger cars per train	6
Restaurant cars per train	1
Type of power	Electrified
Top commercial speed	200 mph
Power consumption (kWh/seat mile)	0.105
- **Infrastructure -**

Length of right-of-way	464 miles
Double track route miles	461 miles
Single track route miles	7 miles
Percentage of double-track	99%
Number of stations	10

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- **Operations -**

Train-set miles per year	2,721,848
Trains per weekday - both directions	24
Trains per weekend - both directions	12
Running time - end-to-end	323 minutes
Running time - NYC-Albany Express	112 minutes
Operations are 18.5 hours/day	0600 to 0030

- The projected baseline annual ridership is 3,400,000 passengers in the year 2010. The average passenger trip length is 218 miles. The occupied passenger seat miles per year are 741,200,000 ($3,400,000 \times 218 = 741,200,000$). Train seat miles are based on train runs per day between New York City - Niagara Falls and New York City - Albany. With 400 seats on each train, train seat miles per year are 1,088,739,200 ($2,721,848 \times 400 = 1,088,739,200$). The average load factor per train is 0.68 passengers per train seat mile ($741,200,000 / 1,088,739,200 = 0.6808$); and
- A preliminary time table for train operations is provided separately.

Labor and Wage Calculations

Labor and wages are based on the following assumptions:

- Work days per employee per year - 230 days (1840 hours) with an allowance of 30 days for vacation, holidays, training and sick leave;
- Employees work a forty hour week;
- Station employees work a ten hour day, four day week; and
- Fringe benefits are 40% of the base salary.

Staff Requirements

The VHRSR organization has a total of 896 personnel. The President's office has 4 personnel and there are 28 personnel performing administrative duties. The balance of the personnel list under Administration, or 232 personnel, operate the stations, perform catering services and are guards. There are 185 personnel in Operations and the maintenance staff totals 447 personnel. An organization chart and a summary of projected salary cost assumptions by position has been provided under separate cover.

The track maintenance crew has 110 employees. The crew works the 1st and 2nd shifts and are on-call in the event of an emergency.

Forty-five track inspectors are assigned on the 1st shift for the daily walking inspection of the track. Each mile of track is visually inspected for defects a minimum of twice each week in accordance with Federal Railroad Administration requirements.

- The Manager for Signals is responsible for maintenance of the signal system to include Central Traffic Control. A maintenance crew of 64 employees is assigned on the 1st and 2nd shifts. All employees are on-call in the event of an emergency;
- The Manager for Catenary/Power is responsible for the maintenance of the catenary and power distribution systems. He has a staff of 68 employees assigned on the 1st and 2nd shifts. All employees are on-call in the event of an emergency; and
- The Manager for Communications maintains all of the system communications to include Central Traffic Control systems. He has 25 signal maintainers assigned on the 1st and 2nd shifts. All employees are on-call in the event of an emergency.

Summary

The annual personnel cost for the operation of the VHSR system between New York City and Niagara Falls is \$45,798,000.

VHSR MATERIAL COSTS

The annual material costs are calculated as a percentage of the capital cost of various elements of the infrastructure. These costs, together with annualized renewal rates are shown in Table 5-3.

Table 5-3. VHSR Material Costs.

<u>Item</u>	<u>Initial Capital Costs</u>	<u>% Renewed During Service Life</u>	<u>Capital Costs to be Renewed</u>	<u>Service Life in Years</u>	<u>O/H Rate (%)</u>
Structures	1,113M	10	111M	100	12
Track	582M	30	175M	30	20
Signaling	285M	25	71M	25	12
Communications	78M	25	20M	25	12
Catenary/Power	258M	25	65M	25	12
Buildings/Stations	68M	20	14M	50	6
Drainage/Roads/Fences	337M	15	51M	30	20

Maintenance of Equipment

Depot Maintenance. Material costs are based on a factor of 0.0069% of the purchase cost of the rolling stock per each 1,000 miles of train-set operations plus 6 percent of the total for warehouse and supply charges. The annual cost is $((0.000069 \times \$355,200,000) \times [2,721,848 / 1000]) / 16 \times 1.06 = \$4,419,486$ or \$4,420,000 annually.

Repair Shop. Annual material costs are based on 1 percent of purchase cost of the rolling stock including maintenance-of-way equipment. The cost is $(0.01 \times \$364,375,422) = \$3,643,754$ or \$3,644,000 annually.

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Coach Rebuilding/Refurbishing. The coaches will be rebuilt/refurbished every nine years at a cost estimated at 25 percent of the original cost. The funds to be set aside annually to rebuild the 96 coaches and 16 restaurant cars are $(\$211,200,000 \times .25) / 9 = \$5,866,667$ or \$5,867,000.

Maintenance of the power units is performed as required and incorporated in the depot and repair shop funding.

Maintenance-of-Way. The cost to maintain the system is based on the initial capital cost, projected service life, and the percentage of each system component to be renewed during its service life. An overhead rate is applied to each component of the infrastructure.

Structures. The material cost for structures renewed during the 100 year service life is $\$1,113,216,283 \times .10 = \$111,321,628$. The average annual cost is $\$111,321,628 \times 1.12 / 100 \text{ years} = \$1,246,802$ or \$1,247,000.

Track. The material cost for track renewed during the service life is $\$582,747,283 \times .30 = \$174,824,185$. The average annual cost is $\$174,824,185 \times 1.2 / 30 \text{ years} = \$6,992,967$ or \$6,993,000.

Signaling. The material cost for signals renewed during the service life is $\$285,465,348 \times .25 = \$71,366,337$. The average annual material cost for signals maintenance is $\$71,366,337 \times 1.12 / 25 \text{ years} = \$3,197,212$ or \$3,198,000.

Communications. The material cost for communications renewed during the service life is $\$78,533,083 \times .25 = \$19,633,271$. The average annual material cost for communications maintenance is $\$19,633,271 \times 1.12 / 25 \text{ years} = \$313,600$ or \$314,000.

Catenary/Power. The material cost for communications renewed during the service life is $\$258,580,373 \times .25 = \$64,645,093$. The average annual material cost for catenary/power maintenance is $\$64,645,093 \times 1.12 / 25 \text{ years} = \$2,896,100$ or \$2,896,000.

Building/Stations. The material cost for buildings and stations renewed during the service life is $\$68,371,443 \times .20 = \$13,674,289$. The average annual material cost for buildings/stations is $\$13,674,289 \times 1.06 / 50 \text{ years} = \$289,895$ or \$290,000.

Drainage/Roads/Fences. The material cost for drainage, roads and fences renewed during the service life is $\$337,770,040 \times .15 = \$50,665,566$. The average annual material cost for drainage/roads/fences is $\$50,665,566 \times 1.20 / 30 \text{ years} = \$2,026,620$ or \$2,027,000.

Other Costs

Contract Services. Services will be contracted for the maintenance of elevators, escalators, and automobiles. Other services such as legal representation and track geometry inspections which do not justify a permanent staff will be contracted. An allowance of \$3,000,000 is provided for these service contracts.

Energy. The energy cost calculation assumes the use of 0.105 kWh per train seat mile at an average cost of \$0.08 per kWh. An additional 1.5 percent is added for shunting of train-sets during non-revenue service hours. The potential of reducing energy costs by regenerative braking was not considered in this analysis. An annual allowance of \$600,000 is provided for house power for the stations and yard and shops. The estimated annual energy cost is $(1,088,739,200 \times 0.105 \times 0.08) \times 1.015 + 600,000 = \$9,882,590$ or \$9,883,000.

Station Cleaning. Station cleaning will be performed under contract with janitorial service companies. The estimated cost for this service is \$60,000 per year for each of the larger stations (Pennsylvania Station plus 5). An annual cost of \$40,000 is estimated for each of the other four stations. The total annual cost for janitorial service is \$520,000.

The cost of operating, cleaning and maintaining parking lots at the stations is assumed to be offset by revenue from the lots.

Station Consumables. An annual allowance of \$350,000 is estimated for consumable supplies at the stations.

Commissions to Travel Agents. Travel agents will receive a 10 percent commission on the cost of tickets sold. The annual commissions paid travel agents are estimated as \$2,000,000.

Train Cleaning Supplies. Consumable cleaning supplies are estimated to cost \$300,000 per year.

Advertising. An allowance of \$1,500,000 per year is provided for advertising.

Insurance. Public liability and property damage insurance costs are estimated at a rate of \$0.003 per passenger-mile. Based on the projection of 741,200,000 passenger-miles (3,400,000 annual ridership

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with an average trip length of 218 miles), the annual insurance cost is \$2,223,600. This does not include any cost for indemnification of the freight railroads.

Administration Consumables. An annual allowance of \$300,000 is provided for consumable supplies.

Sales Staff Consumables. An annual allowance of \$50,000 is provided for consumable supplies.

Summary

The annual personnel costs are \$45,798,000. The maintenance material and other costs total \$51,022,600 annually. The total annual operations and maintenance cost is \$96,820,600. These costs are summarized in Table 5-4.

Table 5-4. Summary of VHSR Operations and Maintenance Cost Estimate (1993 \$).

ITEM		ANNUAL COST IN MILLIONS
Personnel Costs		
Administration		\$ 8.8
Transportation		13.0
Engineering/Maintenance		24.0
Total Personnel Costs		\$45.8
Material Costs		
Equipment Maintenance		\$13.9
Maintenance-of-Way		17.0
Electric Power		9.9
Other Costs		10.2
Total Material Costs		\$51.0
TOTAL OPERATION AND MAINTENANCE COSTS		\$96.8

MAGLEV OPERATIONS AND MAINTENANCE COST ESTIMATE

Operations and Maintenance Costs

The Maglev operations and maintenance costs are estimated based on the cost experience for the German Transrapid TR07 test track at Emsland. Labor costs are based on the experience of passenger rail systems in the United States. With no Maglev system in revenue service at any location in the world, the cost estimate is conservative and actual experience may reduce the overall maintenance costs.

The alignment for the Maglev system is Case TPC-6, the aggressive Thruway alignment in New York State.

Operations and Maintenance Assumptions

Operations and maintenance costs are based on the following assumptions:

- Trains make 12 round trips between New York City and Niagara Falls on weekdays;
- Trains make 5 express round trips between New York City and Albany on weekdays;
- Trains make 6 round trips between New York City to Niagara Falls on weekends;
- Trains make 3 express round trips between New York City and Albany on weekends;
- Trains operated between New York City and Niagara Falls stop at all stations;
- Express trains operated between New York City and Albany do not stop at intermediate stations;
- The trains are electrified and capable of operating at a maximum speed of 300 mph. The average speed for the 453 miles between New York City and Niagara Falls is 187 mph with a travel time of 2 hours and 25 minutes;
- Each New York City to Niagara Falls train has two first class coaches, two high density class coaches, and a restaurant car. There are 60 seats in the first class cars and 100 seats in each high density coach. The seating capacity per train is 320 passengers;
- Each New York City to Albany express train has two first class coaches and two high density class coaches. There are 60 seats in the first class cars and 100 seats in each high density coach. The seating capacity per train is 320 passengers; and

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- The estimated costs are in 1993 dollars for a mature system that has been operating for ten years. The operations and maintenance costs in the initial years of operation should be significantly lower.

System Operations

The system operations are as follows:

- **Equipment -**

Number of train-sets	10
Train-sets in weekday operations	8
Train-sets in weekend operations	6
Type of power	Electrified
Top commercial speed	300 mph
Power consumption (kWh/car-mile)	0.131
- **Infrastructure -**

Length of right-of-way	420 miles
Number of stations	10
- **Operations -**

Car-miles per year	17,637,984
Running time - end-to-end	145 minutes
Running time - NYC-Albany Express	53 minutes
Operations are 18.5 hours/day	0600 to 0030
- The projected annual ridership is 3,835,342 passengers in the year 2010. The average passenger trip length is 218 miles. The occupied passenger seat miles per year are 836,104,556 ($3,835,342 \times 218 = 836,104,556$). Train seat miles are based on train runs per day between New York City - Niagara Falls and New York City - Albany. With 320 seats on each train, train seat miles per year are 1,158,635,520. The average load factor per train is 0.72 passengers per train seat mile ($836,104,556 / 1,158,635,520 = 0.72$) or 72 percent of the seats are occupied; and
- A preliminary time table for train operations has been provided under separate cover.

Labor and Wage Calculations

Labor and wages are based on the following assumptions:

- Work days per employee per year - 230 days (1840 hours) with an allowance of 30 days for vacation, holidays, training and sick leave;
- Employees work a forty-hour week;
- Station employees work a ten-hour day, four day week; and
- Fringe benefits are 40 percent of the base salary.

Staff Requirements

The Maglev organization has a total of 740 personnel. The President's office has 4 personnel, and 217 personnel are assigned under Administration. Twenty-eight personnel listed under Administration perform strictly administrative duties while the balance of this staff, or 189 personnel, operate the stations, perform catering services and are security guards. There are 130 personnel in Operations. The Maintenance staff totals 339 personnel.

An organizational chart and a summary of the projected salary costs by position has been provided under separate cover. Many of the Maglev position responsibilities and staffing of the activities are identical to the VHRS staffing discussed in an appendix to this section. The identical staff positions are listed below but not discussed in detail.

Summary

The annual personnel cost for the operation of the Maglev system between New York City and Niagara Falls is \$39,169,760.

MAGLEV MATERIAL COSTS

The annual material costs are calculated as a percentage of the capital costs of various elements of the infrastructure. These costs, together with the annualized renewal costs, are shown in Table 5-5.

Table 5-5. Maglev Material Costs.

<u>Item</u>	<u>Initial Capital Cost</u>	<u>% Renewed during Service Life</u>	<u>Capital Cost to be Renewed</u>	<u>Service Life in Years</u>
Guideway	2,852M	10	285M	50
Command/Control	193M	25	48M	25
Power System	962M	25	241M	25
Stations/Buildings	189M	20	38M	50
Maintenance/S&I Facilities	226M	20	45M	30

Maintenance of Equipment

Vehicle Maintenance. Material costs are based on the projected life of the vehicle components. Funds not actually utilized for maintenance work will be escrowed for ultimate vehicle replacement.

The vehicle body comprises about 38 percent of the overall cost and has a projected life of 30 years. The average annual funds required for maintenance and replacement are \$259,200,000 (vehicle cost) x 0.38/30 years = \$3,283,200 or \$3,284,000.

The net/control systems are about 22 percent of the overall cost and have a projected life of 10 years. The average annual funds required for maintenance and replacement are \$259,200,000 (vehicle cost) x 0.22/10 years = \$5,720,240 or \$5,720,000.

The magnets are about 34 percent of the overall cost and have a projected life of 15 years. The average annual funds required for maintenance and replacement are \$259,200,000 (vehicle cost) x 0.34/15 years = \$5,875,200 or \$5,875,000.

The levitation and guidance systems are about 6 percent of the overall cost and have a projected life of 30 years. The average annual funds required for maintenance and replacement are \$259,200,000 (vehicle cost) x 0.06/30 years = \$518,400 or \$519,000.

The total annual funds required for vehicle repair/replacement are \$15,398,000.

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Maintenance-of-Way. The cost to maintain the system is based on the capital cost less the sunk costs, the projected service life, and the percentage of each system component to be renewed during its service life.

Guideway. The cost of maintenance material for guideway renewal during the service life is \$285,000,000. The average annual cost is $\$285,000,000 / 50 \text{ years} = \$5,700,000$.

Command & Control System. The cost of maintenance material for the Command & Control System renewal (Central Control Facility, signals and communications) during the service life is \$48,000,000. The average annual cost for command and control system maintenance is $\$48,000,000 / 25 \text{ years} = \$1,920,000$.

Power System. The cost of maintenance material for power system renewal during the service life is \$241,000,000. The average annual material cost for power system maintenance is $\$241,000,000 / 25 \text{ years} = \$9,640,000$.

Stations/Buildings. The cost of maintenance material for stations and buildings renewed during the service life is \$38,000,000. The average annual material cost for communications maintenance is $\$38,200,000 / 50 \text{ years} = \$760,000$.

Maintenance and Service & Inspection Facilities. The cost of maintenance material for the maintenance and S&I facilities renewed during the service life is \$45,000,000. The average annual material cost for maintenance and S&I facility maintenance is $\$45,000,000 / 30 \text{ years} = \$1,500,000$.

Other Costs

Contract Services. Services will be contracted for the maintenance of elevators, escalators, and automotive vehicles. Other services such as legal representation which do not justify a permanent staff will be contracted. An allowance of \$3,000,000 is provided for these service contracts.

Station cleaning will be performed under contract with janitorial service companies. The estimated cost for this service is \$80,000 per year for each of the larger stations (Pennsylvania Station plus 5). An annual cost of \$50,000 is estimated for each of the other four stations. The total annual cost for janitorial service is \$600,000.

The cost of operating, cleaning and maintaining parking lots at the stations is assumed to be offset by revenue from the lots.

The total allowance for contract services is \$3,600,000.

Energy. The energy cost calculation for traction power assumes the use of 0.131 kWh per seat-mile at an average cost of \$0.08 per kWh. The estimated annual traction power energy cost for revenue service is $1,347,937,920 \text{ seat-miles per year} \times 0.131 \text{ kWh /seat-mile} \times \$0.08 / \text{kWh} = \$14,126,389$. An additional 1.5 percent is added for shunting the vehicles during non-revenue service operations or $\$14,126,389 \times 0.15 = \$2,118,960$. An annual allowance of \$1,400,000 is provided for switch operation, tools, battery recharging, house power for lighting, air conditioning and heating the stations and yard and shops. The total annual energy cost is $\$2,118,960 + \$1,400,000 = \$3,518,960$ or \$3,519,000.

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Station Consumables. An annual allowance of \$350,000 is estimated for consumable supplies at the stations.

Commissions to Travel Agents. Travel agents will receive a 10 percent commission on the cost of tickets sold. The annual commissions paid travel agents are estimated at \$2,000,000.

Train Cleaning Supplies. Consumable train cleaning supplies are estimated to cost \$300,000 per year.

Advertising. An allowance of \$1,500,000 per year is provided for advertising.

Insurance. Public liability and property damage insurance costs are estimated at a rate of \$0.003 per passenger-mile. Based on the projection of 836,104,556 passenger-miles (3,835,342 annual ridership with an average trip length of 218 miles), the annual insurance cost is \$2,508,314 or \$2,510,000. This does not include any indemnification costs for operations on the rights-of-way of other passenger or freight railroads.

Administration Consumables. An annual allowance of \$300,000 is provided for consumable supplies.

Sales Staff Consumables. An annual allowance of \$50,000 is provided for consumable supplies.

Summary

The annual personnel costs are \$39,169,760. The maintenance material and other costs total \$61,328,000 annually. The total annual operations and maintenance cost is \$100,497,760. These costs are summarized in Table 5-6.

Table 5-6. Summary of Maglev Operations & Maintenance Cost Estimate (1993 \$).

ITEM	ANNUAL COST IN MILLIONS
Personnel Costs	
Administration	\$ 8.8
Operations	9.5
Maintenance	20.9
Total Personnel Costs	\$39.2
Material Costs	
Vehicle Maintenance	\$15.4
Maintenance-of-Way	19.5
Energy	15.8
Other Costs	10.6
Total Material Costs	\$61.3
TOTAL OPERATION AND MAINTENANCE COSTS	\$100.5

APPENDIX TO SECTION 5

Personnel Descriptions

Maglev position/staffing is the same as the VHSR positions/staffing:

President
Vice President for Administration
Director for Personnel
Director for Procurement
Director for Finance
Director for Sales/Marketing
Director for Stations
Vice President for Operations
Assistant Vice President - Transportation
Director for Road Crews
Director for Central Traffic Control
Director for Labor Relations
Director for Training and Safety
Assistant Vice President - Engineering and Maintenance
Director for Maintenance of Equipment
Manager for Train Cleaning

Maglev staffing that differs from the VHSR organization in the number of positions assigned and/or responsibilities is as follows:

- **Catering Service.** The Manager for Catering Services supervises the catering staff on the trains and the operation of the support/provision facilities located at Pennsylvania Station, Albany Station and the Niagara Falls Station. For 365-day operations, the on-board catering staff has 33 personnel. Ten personnel are assigned to operate the three catering support facilities. It is projected that the caterers and support staff will be paid from the profits of the operation. No costs have been included for the caterers on the trains or for the personnel operating the three catering service facilities at Pennsylvania Station, Albany Station and the Niagara Falls Station.
- **Vehicle Operators.** One operator is assigned to each train. Each operator normally makes two train runs per day with some crews on the express trains making three runs per day. The trains operate from 0600 hours to approximately 0030 hours on weekdays and 0700 hours to approximately 2200 hours on weekends. Express trains will operate between Pennsylvania Station and Albany weekdays and operators are required.

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- **Vehicle Attendants.** One attendant is assigned to each two passenger sections on the trains. They work the same runs as the operators. Forty-three attendants are required for 365 day operations. (If the Maglev trains accelerate at maximum capability upon departing stations, it is recommended that an Attendant be assigned to each passenger vehicle to ensure all passengers are seated prior to departure. This requirement would double the number of attendants required).
- **Yard Operators.** Two yard operators are assigned at the yard on the first and second shifts. One yard operator is on the third shift. To staff this operation 365 days, 8 yard operators are required.
- **Yardmen.** Two yardmen are assigned on the first and second shifts at the yard. One yardman is on the third shift. To staff this operation 365 days, 8 yardmen are required.

Director of Maintenance of Equipment. The Director for Maintenance of equipment supervises the vehicle maintenance and train cleaning operations. He is supported by a manager of each activity and a secretary.

- The Manager of Vehicle Maintenance supervises the schedule maintenance of the train sets and maintenance of way equipment. The staff works a five day work week on the first shift. There are 44 maintenance personnel and one secretary.

Director for Maintenance-of-Way. The Director for Maintenance-of-Way supervises and coordinates the maintenance of the guideways and systemwide systems. His staff includes a manager for guideway maintenance and a manager for fixed facility maintenance. One secretary is assigned to this office.

- The Manager for Guideway Maintenance has a maintenance crew of 146 employees. The staff will assist, as required, with fixed facility maintenance. The staff works the first and second shifts and are on-call in the event of an emergency. One secretary is assigned to this office; and
- The Manager for Fixed Facility Maintenance is responsible for maintenance of the power system and the signal and communications systems to include the Central Traffic

Control facility. This organization also maintains the stations and other fixed facilities. The staff will assist, as required, with the guideway maintenance. A staff of 145 employees is assigned on the first and second shifts. All employees are on-call in the event of an emergency. One secretary is assigned to this office.

VHSR PERSONNEL

President. The President directs all aspects of system operations and administration. An attorney is attached to his office for in-house advice. Law firms will be retained on an as-required basis for legal representation. Two secretaries are assigned to the President's office.

Vice President for Administration. The Vice President for Administration supervises personnel operations, procurement, finance, sales and marketing, and station operations. One secretary is assigned to this office.

Director for Personnel. The Director for Personnel is responsible for supervising benefits and the hiring of staff. He is assisted by two personnel analysts and a secretary.

Director for Procurement. The Director for Procurement is responsible for contracting services such as elevator and escalator maintenance, and specialized personnel safety training. He also negotiates and manages contracts for station cleaning services, automotive vehicle maintenance, the purchase of consumables and material for the operations and maintenance organizations. He has a staff of four procurement specialists and one secretary.

Director for Finance. The Director for Finance is responsible for the payroll and revenue collection. He disburses funds for contract services and material purchases and audits financial operations. His staff consists of three financial specialists, eight revenue collectors and a secretary.

Director for Sales/Marketing. The Director for Sales and Marketing supervises advertising, the sale of advertising space in the stations, and coordination of ticket sales by travel agents. He is assisted by a sales and marketing specialist, a Manager for Catering Service, and a secretary.

- The Manager for Catering Services supervises the catering staff on the trains and the operation of the support/provision facilities located at Pennsylvania Station, Albany Station and the Niagara Falls Station. For 365 day operations, the on-board catering

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staff has 76 personnel. Ten personnel are assigned to operate the three catering support facilities. It is projected that the caterers and support staff will be paid from the profits of the operation. No costs have been included for the caterers on the trains or at the station service centers.

Director for Stations. The Director for Stations is responsible for station operations and management of the security guards. He is supported by one secretary.

- Station Masters work 10 hour shifts. Two 10-hour shifts daily permit the station to open 30 minutes prior to revenue service operations and close 30 minutes after operations cease. Forty Station Masters are required for 365 day operations at the ten stations;
- Ticket Agents work the same shifts as the Station Masters. Forty-six Ticket Agents are required for 365 day operations. On weekdays, two Ticket Agents will be on duty at Pennsylvania Station, Albany Station and the Buffalo Station. At all other stations, one Ticket Agent will be on duty weekdays with one per shift at all stations on weekends. Tickets will be available from vending machines in the stations and from travel agents. Spot checking of tickets is performed by the Conductors and Assistant Conductors on the trains;
- The guards work 8 hour shifts with 24 hour security provided at each of the stations. Forty-eight guards are required to provide station security 365 days per year;
- One guard is assigned on the 1st shift at the Administration Building. Two guards are assigned at Yard/Shops on the 2nd and 3rd shifts. Nine guards are required to provide this security 365 days per year;
- Fifty-seven guards are required to provide coverage 365 days per year; and
- Security of the right-of-way and the unmanned facilities along the right-of-way will be coordinated with local law enforcement agencies.

HSGT Construction Cost Estimates

Vice President for Operations. The Vice President for Operations supervises the train operations and the maintenance of the system. He is assisted by an Assistant Vice President - Transportation and an Assistant Vice President - Engineering and Maintenance. One secretary is assigned to this office.

Assistant Vice President - Transportation. The Assistant Vice President - Transportation supervises the road crews, Central Traffic Control (CTC) operations, labor relations, and the training and safety programs. His staff has four Directors and a secretary.

Director for Road Crews. The Director for Road Crews assigns and supervises the engineers, conductors and assistant conductors on revenue service trains. He also supervises the switch engineers and yardmen. He is assigned one secretary.

- One Engineer is assigned to each train with a 0.67 driving/duty ratio (5.38 hours driving per 8 hour shift). Each engineer makes one train run per day. The train runs end at locations other than the Engineers' home stations which will require overnight accommodations. The trains will operate from 0600 hours to 0030 hours on weekdays and 0700 hours to 2230 hours on weekends. Two express trains will operate between Pennsylvania Station and Albany each morning and evening on weekdays with one train each morning and evening on weekend days. For 365 day operations, 38 Engineers are required;
- One Conductor and one Assistant Conductor are assigned to each train. They work the same runs as the Engineers. Thirty-eight Conductors and 38 Assistant Conductors are required for 365 day operations;
- Three Switch Engineers are assigned at the yard on the first and second shifts. One Switch Engineer is on the third shift. To staff this operation 365 days, 11 Switch Engineers are required; and
- Three Yardmen are assigned on the first and second shifts at the yard. One Yardman is on the third shift. To staff this operation 365 days, 11 Yardmen are required.

HSGT Construction Cost Estimates

Director for Central Traffic Control. The Director for Central Traffic Control (CTC) supervises the CTC Managers, Traffic Dispatchers, Power Supply Managers, and their assistants. He is assigned one secretary.

- One CTC Manager, Traffic Dispatcher, and Power Supply Manager is assigned on each eight hour shift (three shifts) with the CTC operational 24 hours daily. Five personnel are required for each position for 365 day operations; and
- One assistant works with the Traffic Dispatcher and one with the Power Supply Manager on the first two shifts (primary period of revenue service). One assistant supports both positions on the third shift. Eight assistants are required for 365 day operations.

Director for Labor Relations. The Director for Labor Relations works with all elements of the organization. He is assisted by two labor relations specialists and a secretary.

Director for Training and Safety. The Director for Training and Safety directs the development and conduct of safety training and inspections. His staff consists of four training/safety specialists, eight Roadmasters, and a secretary. The Roadmasters will inspect the operations and safety of all aspects of the train operations.

Assistant Vice President - Engineering and Maintenance. The Vice President for Maintenance supervises the maintenance of equipment and the maintenance-of-way operations. He is assisted by two Directors and a secretary.

Director for Maintenance of Equipment. The Director for Maintenance of Equipment supervises depot maintenance, the repair shop, and train cleaning. He is supported by a Manager for each activity and a secretary.

- The Manager for Depot Maintenance supervises the scheduled maintenance of the train-sets and maintenance-of-way equipment. Maintenance beyond the capability of the organization will be contracted out. The staff works a five day week on the 1st shift. There are 30 maintenance personnel and one secretary;

HSGT Construction Cost Estimates

- The Manager of the Repair Shop supervises the unscheduled repair of the train-sets and other equipment. The Repair Shop operates 365 days with personnel assigned to the 1st and 2nd shifts. The staff consists of 40 employees with an average of 15 personnel on the 1st shift and 10 on the 2nd shift. One secretary is assigned; and
- The Manager for Train Cleaning supervises the light cleaning at the stations and the third day thorough cleaning and washing of the trains at the yard. Two cleaners per shift (three shifts) are assigned at Pennsylvania Station, Albany Station and the Niagara Falls Station for light cleaning during turnbacks and overnight storage. Four personnel are assigned at the yard on the 1st shift each day for the thorough cleaning and washing of the trains. For 365 day operations, a cleaning staff of 35 personnel is required.

Director for Maintenance-of-Way. The Director for Maintenance-of-Way supervises and coordinates the maintenance of track and systemwide systems. His staff includes an Assistant Director for Track Maintenance, and Managers for Signals, Catenary/Power, and Communications. One secretary is assigned to this office.

- The Assistant Director for Track Maintenance has four Supervisors with each responsible for the territory covered by two maintenance-of-way stations. The Supervisors are supported by eight senior foremen with one assigned to each maintenance-of-way station. One secretary is assigned.

Section 6

ECONOMIC BENEFITS

INTRODUCTION

A VHSR/Maglev system through New York State would provide significant benefits to the region far above simply moving people potentially faster and cheaper than the existing modes. The system could profoundly affect travel patterns, where people live and work, where development of commercial, residential, and even industrial activity takes place, as well as the regional economy. More goods and services could be produced and consumed as a result of constructing and operating the system. By providing workers faster access to their existing jobs, or potential workers access to emerging labor markets, it may raise productivity in the workplace. It might even relieve congestion at airports or on roadways and help avoid or forestall the cost of unnecessary improvements to other modes.

A major investment in infrastructure such as a VHSR or Maglev system may result in lowering individual (and perhaps societal) travel costs, a major determinant for travel demand patterns. Travel costs are a function of the out-of-pocket costs of travel, such as fares, tolls, gasoline purchased, etc., and the cost of time spent traveling, a product of time spent and the value of that time that could have been spent in other productive activities. The time spent traveling not only involves the time spent in the line

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haul portion of the trip (in the automobile or on the aircraft) but also the time spent gaining access to the facility (such as time spent en route to stations, or at stations or airports waiting for the line haul portion of the trip to commence). A major question with the implementation of a VHSR/Maglev system in New York State is whether it would result in significant travel cost savings to its users. This is discussed in detail in Section 3.

A second major category of economic benefits provided by the introduction of a VHSR/Maglev system within the region is the employment and regional output created as a result of both the initial construction and the ongoing operation and maintenance of the system. Such job creation and local and regional output spin-offs result from the so-called "multiplier" effects of a large public works program, particularly if a significant share of the program activities is carried out locally, by local firms, local subsidiaries of out-of-region or even multinational firms. An advanced rail program is likely to generate numerous technological spin-offs from the myriad of research and development activities associated with delivering the system, similar to the industrial and commercial product generation following the space program. Such spin-offs will not be limited to industrial and commercial processes either. There might be significant advances in consumer goods technology from an advanced rail program, and this effect definitely raises living standards and overall economic well being.

Just how does a major public works program generate such economic benefits? If a VHSR/Maglev system is introduced in New York State, the first round of economic benefits that will occur will emanate from constructing the system, and the "multiplier" effects of spending the construction dollars on various businesses and employment activities within the state. Many types of skilled labor will be required for the construction process. New workers from New York State and beyond will need to be hired, trained, re-equipped, outfitted, managed, administered and be covered by occupational health and safety standards, health plans, affordable housing, adequate schooling and attractive recreational

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facilities. The major types of jobs that will be created are likely to be for general laborers, electricians, machinery and vehicle equipment operators, repair workers, managers and other transportation industry-related workers hired from the region. Clearly, more jobs translates into higher income tax revenues for the state, as well as higher tax revenues for all localities within the state resulting from the increased purchasing activities that these new jobs will generate.

Many different types of materials will need to be purchased, refined, designed for specific uses and reconfigured. Once again, most of these equipment purchases could be supplied by local or regional businesses, or there will arise incentives for out-of-state firms to establish special plants within the state to supply the required materials for the construction process. The key industries that will be involved, regardless of the system technology that will be implemented, will include primary metal products (rails, wire and cable manufacturers), fabricated metal products, electrical equipment, concrete, stone and gravel, lumber and wood, petroleum products and professional and managerial services. A Maglev system will likely involve more advanced products, such as heavy equipment associated with the guiderail, heavy electro-magnetic equipment, and so on.

Furthermore, there will be secondary and continuing economic benefits from operating and maintaining a VHSR/Maglev system within the state, as well as from the economic spin-offs of the operating expenditures on local businesses and employment activities. Such jobs created and business activities sparked are likely to be the more permanent aspects of implementing an advanced rail system within New York State. That is, while the construction process may be fruitful and productive for local employment and business opportunities, such benefits are likely to be temporary and will end when construction is accomplished. The long-term and permanent benefits will arise when the system is in place. Once developed, the system will act as an economic catalyst for further and more permanent business and employment opportunities because of the significant labor and material requirements of

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ongoing operation and maintenance. The bulk of the new jobs created during the operation of the system will likely be in the transportation industry, for rail repair and maintenance, management and other professional services, as well as the sectors that will serve the travellers on the system including retail establishments, hotels and other lodgings, personal services, telecommunications and the recreation industry. As an engine of long-term growth, high speed rail in New York State could well replicate the economic role that the original railroads played in the development of the American frontier.

A third major category of economic benefits introduced by implementing a VHSR/Maglev system in New York State includes societal and community benefits. Advanced rail systems will provide a significant boon to the large number of transportation disadvantaged residents of served cities. The transportation disadvantaged include all individuals whose access to convenient transportation is limited, such as the elderly, the infirm, the handicapped, the young and low income groups. As the majority of employment, cultural, administrative and artistic centers, as well as a large number of health care, education and other special services remain located in urban areas, improvements in affordable, convenient and fast transportation to and from urban areas will have very important benefits for such residents of the state.

The financial benefits from implementing a VHSR/Maglev system constitute the fourth major category of economic benefits. Financial benefits accrue to the operator of the system, and include the net revenues from passenger and freight fares and charges, revenues from other uses of the right-of-way (such as fiber optic and telecommunication uses paying fees for access) and revenues from station concessions and leases to retail and commercial enterprise. To the state itself, such financial benefits naturally generate additional tax revenues, as well as project a sense of economic well-being.

Finally, one of the most important categories of economic benefits include the energy and environmental benefits of introducing an efficient carrier of people and freight. Such benefits are distinct from the actual tonnage of pollutants saved by having travellers use the VHSR/Maglev system, or the tons of fuel saved. Rather, they represent the economic value of such pollutants emitted. That is, the dollar (or monetized) value to society in general, or to New York State in particular, from having fewer private automobiles on the roads, fewer flights, or lower emissions. Section 4 discusses some of the relative impacts and benefits of a VHSR/Maglev system.

In this section of our report, we will turn first to the job creation and output-generating potential of a new VHSR or Maglev system in New York State. We will then summarize the results from the other major categories of economic benefits. Clearly, justifying the rather significant public and private resources that will need to be martialled and devoted to the development and delivery of such a system will depend on the extent of the economic returns or benefits to that investment. The wider the spread of benefits realized (the more people who will benefit), the more likely it is that public and private commitments of time, materials and resources can be made to developing such a system.

ANALYZING THE ECONOMIC IMPACTS OF VHSR/MAGLEV ON STATEWIDE EARNINGS AND EMPLOYMENT

To determine the economic feasibility of building a VHSR/Maglev system in New York, and to justify the use of government expenditures and other assistance to construct and operate such a system, a detailed assessment of economic benefits must be produced. To do this, we had to first determine the dollar value of all direct expenditures to be made on the construction, operation and maintenance of the VHSR/Maglev system. Using this data, a set of economic multipliers supplied by an input-output modelling process known as RIMS-II was used to determine the indirect economic effects of the direct

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expenditures, including the effects on all businesses related to the direct construction and ongoing operation and maintenance of the VHSR system. These range from the suppliers of goods and services (raw steel, transportation services, accounting services, etc.), to the suppliers of manpower employed by this work.

The first round of economic benefits to New York will come from constructing the system and the "multiplier" effects of spending these construction dollars on various business and employment activities within the state. Secondary or continuing benefits will also accrue from operating and maintaining the system and the economic spin-offs of the operating cost expenditures, the multiplier effects of these expenditures, and the business and jobs created as a result of the ongoing operation and maintenance of the system.

THE RIMS II MODEL

The set of multipliers which were used to determine the indirect economic effects of construction and operations of each VHSR/Maglev alternative has been developed by the U.S. Department of Commerce, Bureau of Economic Analysis (BEA), in its RIMS II model. This model is used by the New York State Energy Office as well as many other agencies at the state and local level to account for interindustry relationships within specified regions, since those relationships largely determine how regional economies respond to projects and program changes.

RIMS II is based on a framework called an input-output (I-O) table. An I-O table shows, for each industry, the industrial distributions of inputs purchased and outputs sold. This framework is used to quantify, for each dollar spent in that industry, a) the increase in employment; b) the increase in total

earnings (wages, salaries, benefits, and proprietors' income); and c) the increase in total regional output (gross receipts or sales) over all industries generated as a result of activity in that industry.

RIMS II data is derived from two sources: The BEA's national I-O table, which shows the input and output structure for 500 U.S. industries, and the BEA's county-level wage and salary data. The latter data set can be used to adjust the national I-O table to produce multipliers which more accurately reflect a region's industrial structure and trading patterns. This adjustment has already been done for New York State, and can be done upon request for other one-county or multi-county groupings within the state. We used RIMS II multipliers adjusted for New York State.

Advantages of the RIMS II Model

The benefits of using the RIMS II model lie in its low cost, relative ease of use, widespread acceptance and flexibility. Empirical tests indicate that RIMS II yields multipliers which are not substantially different in magnitude from those generated by regional I-O models based on costly regional survey data. The model is flexible in many ways, including the fact that it can be used at two levels of detail: multipliers exist for a set of 39 industries and also at a 500-industry level of detail. The multipliers can also be adjusted to accommodate the specific procurement behavior of known suppliers, or any in-state sourcing requirements. More complicated models such as the Wharton Econometric Forecasting Model are more expensive to run, and have to be more carefully fine tuned in order to yield useful results.

We considered the cost of the RIMS II model and its widespread acceptance compared to other approaches, and judged it to be the appropriate model to use for determining the state-wide economic benefits of constructing and operating a VHSR/Maglev system in New York State.

Inputs to and Outputs of the RIMS II Model

Input. The basic input required for the RIMS II model is the total expenditure, in dollar terms, of:

- One-time construction-related costs; and
- Ongoing annual operation and maintenance expenditures.

The more detailed the expenditures are in terms of the type of industries involved, the better the output will be. (For example, it is better to know that expenditures are being made specifically on products from the "motors and generators manufacturing" industry, than from the broader category of "electric & electronic equipment manufacturing".)

The second layer of detail is the geographical source of procurement for the above expenditures. The goal here is to determine as accurately as possible the portion of direct and indirect expenditures which will be spent in New York State. Any information here can be useful in refining the RIMS II multipliers. We determined, for example, the domestic (i.e., New York State) content of the rolling stock (only 20 percent for the steel wheel alternative) and, at the other extreme, the domestic content (100 percent) of the fencing costs. We used our best judgements in this area and believe that, on the whole, these are reasonable.

Separate capital and ongoing operations and maintenance costs were not developed in sufficient detail for a similar analysis of the incremental (tilt) alternative. It is expected, however, that significant additional jobs and statewide earnings will be generated by implementing an

incremental rail option in New York, although by amounts less than those generated by the VHSR or Maglev option.

Output. For each dollar of expenditure spent on both one-time construction and ongoing operations and maintenance activities, the RIMS II model estimated:

- **Employment** The number of additional jobs created in New York State;
- **Earnings** The dollar change in state-wide earnings (wages, salaries, benefits, and proprietor earnings); and
- **Output** The dollar change in New York State's output (measured in terms of gross receipts).

Tables 6-1 through 6-4 summarize the results for the RIMS II multiplier runs. In particular:

- Constructing a steel wheel VHSR system will result in 89,619 temporary jobs, over \$12 billion in enhanced output for New York State and an increase in household earnings of over \$3.7 billion;
- Operating and maintaining the system over a period of 20 years will create over 30,000 person-years of employment jobs, over \$3.6 billion in increased state output and over \$1.2 billion in increased household earnings;

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- Constructing a Maglev system will result in over 190,000 temporary jobs during the construction period, over \$25.5 billion in enhanced state output and \$7.9 billion in increased household earnings; and
- Operating and maintaining a Maglev system over a period of 20 years will create over 37,000 person-years of employment jobs, over \$4.4 billion in increased state output and \$1.5 billion in enhanced household earnings.

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**Table 6-1. Total Impact on NYS Output, Household Income, and Employment
from a VHSR Construction Project.**

Cost Element	Construction Cost (1993 Dollars)	Costs w/ 20% Cont (1993 Dollars)	% of Exp. in New York	New York Cost (1993 Dollars)	Total Output for New York Economy (1993 Dollars)	Household Income (1993 Dollars)	Employment (person years)
Trackwork	1,833,500,000	2,200,200,000	100%	2,200,200,000	4,288,189,800	1,288,458,940	31,650
Roadway Preparation	161,200,000	193,440,000	100%	193,440,000	377,014,580	113,104,368	2,783
Structures	1,089,200,000	1,307,040,000	100%	1,307,040,000	2,547,420,960	764,226,288	18,802
Fencing	115,800,000	138,720,000	100%	138,720,000	270,365,280	81,109,584	1,966
Crossing Protection	0	0	N/A	N/A	N/A	N/A	N/A
Yards/Shops & Way Stations	51,700,000	62,040,000	75%	46,530,000	90,686,970	27,208,091	669
Stations & Admin. Bldg.	64,600,000	77,520,000	90%	69,768,000	135,977,832	40,793,350	1,004
Electrification	999,500,000	1,199,400,000	90%	1,079,460,000	2,103,867,540	631,160,262	15,528
Aerial Utility Relocation	22,600,000	27,120,000	100%	27,120,000	52,856,880	15,857,064	390
Signalization	265,500,000	342,800,000	75%	256,950,000	500,798,550	150,238,665	3,696
Communications	78,500,000	94,200,000	95%	89,490,000	174,416,010	52,324,803	1,287
Rolling Stock	326,400,000	391,680,000	20%	78,336,000	143,887,565	41,361,408	812
Engineering/Management	905,100,000	905,100,000	75%	678,825,000	1,344,005,618	537,765,165	11,002
TOTALS	\$6,833,600,000	\$8,938,230,000	89%	\$8,166,879,000	\$12,029,484,664	\$3,741,603,988	89,619

Input Category	Output Multipliers	Earnings Multipliers	Employment Multipliers*
Construction: New	1.9490	0.5847	14.4
Manufacturing: Transp. Eqpt.	1.8368	0.5280	10.4
Services: Business	1.9799	0.7922	16.2

* Adjusted for 1993 \$.

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Table 6-2. Annual Output, Household Income, and Employment Benefit from Operation and Maintenance of a New York State VHSR Project.

Year	Projected O&M Costs	Total Output for NY Economy	Household Income	Cumulative Employment (Person Years)
Year 1	\$96,800,000 *	\$185,071,920 *	\$63,646,000 *	1,502
Year 2	\$100,284,800	\$191,734,509	\$65,937,256	3,004
Year 3	\$103,895,053	\$198,636,951	\$68,310,997	4,506
Year 4	\$107,635,275	\$205,787,882	\$70,770,193	6,008
Year 5	\$111,510,145	\$213,196,245	\$73,317,920	7,510
Year 6	\$115,524,510	\$220,871,310	\$75,957,365	9,012
Year 7	\$119,683,392	\$228,822,677	\$78,691,830	10,514
Year 8	\$123,991,994	\$237,060,294	\$81,524,736	12,015
Year 9	\$128,455,706	\$245,594,464	\$84,459,627	13,517
Year 10	\$133,080,111	\$254,435,865	\$87,500,173	15,019
Year 11	\$137,870,995	\$263,595,556	\$90,650,180	16,521
Year 12	\$142,834,351	\$273,084,996	\$93,913,586	18,023
Year 13	\$147,976,388	\$282,916,056	\$97,294,475	19,525
Year 14	\$153,303,538	\$293,101,034	\$100,797,076	21,027
Year 15	\$158,822,465	\$303,652,671	\$104,425,771	22,529
Year 16	\$164,540,074	\$314,584,168	\$108,185,099	24,031
Year 17	\$170,463,517	\$325,909,198	\$112,079,762	25,533
Year 18	\$176,600,203	\$337,641,929	\$116,114,634	27,035
Year 19	\$182,957,811	\$349,797,038	\$120,294,761	28,537
Year 20	\$189,544,292	\$362,389,732	\$124,625,372	30,039
Net Present Value	\$1,868,725,869	\$3,572,816,988	\$1,228,687,259	

* First year's operating & maintenance costs are expressed in 1993 dollars.
The rate of inflation used beyond that is 3.6% annually.

Table 6-3. Total Impact on NYS Output, Household Income, and Employment from a Maglev Construction Project.

Cost Element	Construction Cost (1993 Dollars)	Costs w/ 20% Cont (1993 Dollars)	% of Exp. in New York	New York Cost (1993 Dollars)	Total Output for New York Economy (1993 Dollars)	Household Income (1993 Dollars)	Employment (person years)
Guideway	7,725,000,000	9,270,000,000	80%	7,416,000,000	14,453,784,000	4,336,135,200	106,680
Roadways/Parking Lots	8,800,000	10,560,000	N/A	N/A	N/A	N/A	N/A
Fencing	15,100,000	18,120,000	N/A	N/A	N/A	N/A	N/A
Crossing Protection	0	0	N/A	0	0	0	0
Yards & Shops	103,100,000	123,720,000	75%	92,790,000	180,847,710	54,254,313	1,335
Service & Inspection Facilities	154,500,000	185,400,000	75%	139,050,000	271,008,450	81,302,535	2,000
R.O.W. Maintenance Centers	21,400,000	25,680,000	75%	19,260,000	37,537,740	11,261,322	277
Stations & Admin. Bldg.	324,500,000	389,400,000	90%	350,460,000	683,046,540	204,913,962	5,041
Power System	2,689,200,000	3,227,040,000	85%	2,742,984,000	5,346,075,816	1,603,822,745	39,458
Command/Control System	654,200,000	785,040,000	75%	588,780,000	1,147,532,220	344,259,666	8,470
Vehicles/Special Equipment	277,200,000	332,640,000	15%	49,696,000	91,648,973	26,345,068	517
Engineering/Management	2,155,100,000	2,155,100,000	75%	1,616,325,000	3,200,161,868	1,280,452,685	26,195
TOTALS	\$14,128,198,808	\$16,822,700,008	79%	\$13,016,546,008	\$28,411,643,316	\$7,942,747,496	189,974

Input Category	Output Multipliers	Earnings Multipliers	Employment Multipliers*
Construction: New	1.9490	0.5847	14.4
Manufacturing: Transp. Eqpt.	1.8368	0.5280	10.4
Services: Business	1.9799	0.7922	16.2

* Adjusted for 1993 \$.

Table 6-4. Annual Output, Household Income, and Employment Benefit from Operation and Maintenance of a New York State Maglev Project.

Year	Projected O&M Costs	Total Output for NY Economy	Household Income	Cumulative Employment (Person Years)
Year 1	\$119,400,000 *	\$228,280,860 *	\$78,505,500 *	1,853
Year 2	\$123,698,400	\$236,498,971	\$81,331,698	3,705
Year 3	\$128,151,542	\$245,012,934	\$84,259,639	5,558
Year 4	\$132,764,998	\$253,833,400	\$87,292,986	7,410
Year 5	\$137,544,538	\$262,971,402	\$90,435,534	9,263
Year 6	\$142,496,141	\$272,438,372	\$93,691,213	11,116
Year 7	\$147,626,002	\$282,246,154	\$97,064,097	12,968
Year 8	\$152,940,538	\$292,407,015	\$100,558,404	14,821
Year 9	\$158,446,398	\$302,933,668	\$104,178,507	16,673
Year 10	\$164,150,468	\$313,839,280	\$107,928,933	18,526
Year 11	\$170,059,885	\$325,137,494	\$111,814,374	20,378
Year 12	\$176,182,041	\$336,842,444	\$115,839,692	22,231
Year 13	\$182,524,594	\$348,968,772	\$120,009,921	24,084
Year 14	\$189,095,480	\$361,531,648	\$124,330,278	25,936
Year 15	\$195,902,917	\$374,546,787	\$128,806,168	27,789
Year 16	\$202,955,422	\$388,030,471	\$133,443,190	29,641
Year 17	\$210,261,817	\$401,999,568	\$138,247,145	31,494
Year 18	\$217,831,243	\$416,471,553	\$143,224,042	33,347
Year 19	\$225,673,167	\$431,464,528	\$148,380,107	35,199
Year 20	\$233,797,401	\$446,997,252	\$153,721,791	37,052
Net Present Value	\$2,305,019,305	\$4,406,966,409	\$1,515,550,193	

* First year's operating & maintenance costs are expressed in 1993 dollars.
The rate of inflation used beyond that is 3.6% annually.

**ASSESSING THE ECONOMIC EFFECTS OF VHRS/MAGLEV
ON LAND USE AND LAND VALUES**

VHRS/Maglev systems could affect land use and property values in two opposite ways. First, through increasing the accessibility of sites (and therefore of the commercial, industrial, retail or residential activities associated with those sites) within their service area, they may increase land and property values via increasing bid rents, or by increasing the speculative value of undeveloped parcels. Second, because of the noise, visual or air pollution that may result from such systems, or the perceptions that such systems may cause such pollution, VHRS/Maglev systems could have a depressing effect on land and buildings in close proximity.

Negative effects on land values are most often observed with highway corridors where adjoining properties suffer significant declines in value. Several rail transit studies, however, have also confirmed the negative impacts on land values in proximity to rapid transit lines, with a continuous decline of those negative impacts with distance from the line. However, we would expect that the negative impacts from noise, air and visual pollution to be more than compensated by the positive effects (or "externalities") provided by improved access. Indeed, the evidence almost overwhelmingly suggests that property values do indeed capitalize transportation cost savings realized through improved access. Thus, transit lines have been observed to increase land values in the areas or hinterlands that they serve.

In particular, studies of service areas have shown that the opening of suburban rail rapid transit lines significantly increases property values, with the most dramatic consequences in the surrounding station areas where property appreciation is greatest. However, these positive price effects usually diminish rapidly with distance from the station area, with noticeable impacts being minimal beyond 1500 feet (for example, beyond 5 to 7 minutes walking time).

An even more difficult issue is determining the impact that VHRS/Maglev systems would have upon urban form and structure. There has been a dearth of studies determining the suburbanizing effects of freeway systems in the urban region and the negative consequences for the urban core (for example, in St. Louis). And of course, policy makers have focused on trying to use transit improvements to rejuvenate the core areas of the older and more declining metropolitan areas. But it is still unclear whether rail investments can lead directly to a recentralizing and rebirth of older central areas.

The problem with VHSR or Maglev systems is that although they share many characteristics with other types of rail transportation, they are somewhat distinct. Any inferences that can be drawn from the effects of rail rapid transit systems on land or property values or on urban form in the U.S. may or may not be applicable to a Maglev system. VHSR/Maglev systems will likely serve more regional business travelers and leisure trips, not the daily commuting trips that are more characteristic of urban transit lines. Not only would origin and destination patterns be different, but the frequency of services would differ, with the result that the total number of arriving or departing passengers at station terminals would be much lower than for urban transit stations. Indeed, as one report recently suggested, VHSR/Maglev station area impacts might more closely resemble those observed at regional airports than with urban rail transit stations.

To summarize, we can make a few observations:

- VHSR/Maglev systems can be predicted to positively impact property values and land development around station areas;
- For the reasons explained above, this type of economic redevelopment will not occur with the same level of intensity as that associated with most urban rail transit stations, although the range of influence of VHSR/Maglev systems may extend far beyond the immediate station areas;
- Existing land use conditions and/or constraints, such as growth management policies, zoning ordinances and other government planning policies will greatly determine the extent of any positive effects on land values, or the shape and form of any effects on land uses;
- A VHSR system that follows the general alignment of an existing highway or rail corridor will probably not result in significant new or additional noise externalities, resulting in fewer deleterious effects on surrounding land values;
- A VHSR/Maglev guideway would, however, constitute a visual impairment. Whether the system would contain overhead wires or an elevated guideway for power, there is no doubt that there is a potential for depressing adjacent land values, although intelligent design and architectural advances could mitigate the extent of this effect;

- Experience with existing VHSR systems in France have illustrated the negative separation effects of dividing large parcels of (particularly agricultural) land and reducing cross-corridor access. Since line crossings are expensive, we would expect that a VHSR/Maglev system in New York State might have the potential to exhibit similar limitations of access, which negatively impact land values;
- Implementing a system in the state would consume vast tracts of land that has other uses. From the land acquisition standpoint, as long as the public (user and non-user) benefits from the VHSR/Maglev system outweigh the value of the uses of the land in its existing state, then the system is economically worthwhile. Certainly, the economies of scale of a "mass transit" system such as VHSR/Maglev (in other words, the efficiency of carrying many people by rail versus providing the equivalent capacity through building or widening highways) should also be considered;
- Studies on the French TGV have shown a general contribution of the system to land value appreciation as well as economic development. However, by itself, the TGV did not seem to figure prominently in plant or firm location decisions, the expansion of business markets or in increases in tourism. Indeed, while there have been signs of generation of commercial activity at the major termini, very little development has occurred around the intermediate station stops; and
- The experience in France suggests that New York State's VHSR/Maglev system be viewed as a potential contributor to the overall regional travel network, improving the efficiency of travel and enhancing overall productivity, rather than viewed as a generator of specific local business activity and/or newly developed real estate around all but the most select station areas.

SPECIFIC LOCAL BUSINESSES OR SERVICES THAT MIGHT BENEFIT FROM VHSR/MAGLEV

There is no question that introducing a system of VHSR/Maglev of such a size and scope as in New York State will involve a myriad of locally or regionally provided industries, firms and services. Not only would there be benefits from new types of technology and technological spin-offs from the system, but the typical activities associated with planning, designing, managing, constructing, operating and even regulating such a large system will generate significant new business opportunities.

Table 6-5 lists some services that could be stimulated by the introduction of a VHSR/Maglev system in New York State.

A major question with the implementation of a VHSR/Maglev system in New York State is whether it would result in significant travel cost savings to its users. That is the focus of this section which examines and determines the transportation economic benefits of implementing the system.

The Do Nothing Alternative

We have characterized the benefits of implementing a VHSR/Maglev system within five basic categories listed below. The benefits of each of the high-speed ground transportation system (HSGT) alternatives are, in effect, the costs of not implementing a high speed rail system.

Many of the benefits of VHSR/Maglev result from a reduction in the number of intercity automobile and air trips. The demand for auto travel continues to grow as population and vehicle ownership rates increase, and as development occurs in ever more distant suburbs. As commuter traffic grows, it competes with intercity traffic for the same road links. Similarly, as the demand for national and international air traffic grows, there is less runway and terminal capacity to absorb growth in air passengers traveling within New York State. Without the development of a high speed ground transportation system, all growth in demand for intercity travel will have to be absorbed by these existing systems. Costs and benefits of HSGT, therefore, cannot be evaluated alone, but must be considered along with the costs and benefits of increasing congestion and delays for existing modes in the short term, and having to expand or build new roads and air facilities in the longer term.

Table 6-5. Representative Industries Which Could be Supplied by New York State Firms in the Construction and Operation of a HSGT System.

Computer software and hardware industries
Systems integration
Civil and structural engineering
Communications software and hardware
Signaling equipment and design
Rolling stock, vehicle and parts manufacturers
Utilities
Railroad tie manufacturers
Concrete suppliers
Steel fabricators
Steel manufacturers
Advanced systems engineering
Superconducting magnets industry
Furniture and fixtures
Motor, Generators, and power supplies
Electric components manufacturing
Construction equipment manufacture and rental
Concessionaires
Temporary and permanent fencing and barricades
Research facilities and universities
Construction contractors

Transportation Benefits are the passengers' total travel time savings, which, when valued at rates approximated by the rate of take home pay, add up to over \$17 million dollars annually for even the slowest of the alternatives studied (HSR Baseline). The majority of the value of passenger time savings comes from business travelers, whose time is more highly valued than that of the average non-business traveler.

Economic and Financial Analyses

Economic Benefits include the increase in jobs, output, and household income that would be directly and indirectly generated by the construction, maintenance, and operation of a VHSR/Maglev system. Every dollar spent on implementing an HSGT system is subject to a multiplier effect, as new employees spend their earnings, and affected firms buy construction and other supplies. Importantly, much of the materials and equipment needed to build and operate the systems studied can be supplied by firms located within New York State. Benefits would also be realized through the increased efficiency of the in-state travel network.

Other economic benefits would originate from the prestige and technological spin-offs that would be expected to occur if a new rail transportation technology was implemented in the state.

Societal/Community Benefits These include a range of benefits resulting from reduced auto congestion and improved access between cities along the rail line. VHSR/Maglev systems will be a significant boon to the large number of transportation disadvantaged residents of served cities. The transportation disadvantaged include all individuals whose access to convenient transportation is limited, such as the elderly, the handicapped, the young, and low income groups. As the majority of employment opportunities, as well as a large number of health care, education, and other special services remain located in urban areas, improvements in affordable transportation to and from cities is very important for these groups.

Environmental Benefits These accrue largely from the reduction in the use of auto and air travel, forms of transportation which have larger environmental impacts than VHSR/Maglev. These impacts include air pollution from emissions, noise impacts, and, particularly for automobiles, casualty, and property damage from accidents.

As demand for intercity travel in New York State continues to increase, there would also be significant environmental impacts caused by the future expansion and addition of roadways, runways, and terminals. These impacts could be avoided or lessened by the introduction of a VHSR/Maglev system. It should be noted that some of the VHSR/Maglev alignments studied would also require the taking of land for a transportation corridor; however, the capacity of a rail corridor would be much greater than a similarly sized highway corridor, with much less traffic and emissions impact to surrounding neighborhoods.

Economic and Financial Analyses

Financial Benefits include the net revenues from passenger fares and freight to the operators of the system. Financial benefits also include the savings from not having to expand or add to the current automobile and air transportation facilities to meet the future expected increase in demand. Savings would be made on both construction and ongoing maintenance of any new facilities. It should also be pointed out that state tax revenues would increase as new jobs are created and new spending takes place to build and operate a VHSR/Maglev system.

As demand for intercity travel in New York State continues to increase, there would also be significant environmental impacts caused by the future expansion of roadways, runways and terminals. These impacts could be avoided or lessened by the introduction of a VHSR/Maglev system. It should be noted that some of the VHSR/ Maglev alignments studied also would required the taking of land for a transportation corridor; however the capacity of a rail corridor or Maglev guideway would be significantly greater than a highway sized to carry the same capacity, with less traffic and emissions in the surrounding neighborhoods.

ECONOMIC BENEFITS: SUMMARY

Implementing a VHSR/Maglev system in New York State will thus generate the following economic and financial benefits:

Job creation, output, earnings and tax generation, high technology spin-offs:

- Building a new Maglev system has the potential of creating up to 190,000 temporary jobs during the construction period, increase State output by \$25 billion, and enhance household earnings by more than \$7.8 billion. Over a 20 year period, operating and maintaining a new Maglev system in the State has the potential of creating more than 37,000 person-years of employment jobs, increasing State output by more than \$3.4 billion, and enhancing household earnings by \$1.5 billion. Many of the new jobs, business and commercial activity created will be a direct result of the numerous technological spin-offs from developing advanced technology.
- Constructing a VHSR system has the potential of creating 90,000 temporary jobs throughout the State, raising State output by more than \$12 billion, and increasing

household earnings by more than \$3.6 billion. Over a twenty year period, operating and maintaining the high speed, steel-wheel alternative would yield more permanent, long-term benefits, with the potential of generating more than 30,000 person-years of employment, raising State output by \$3.5 billion, and increasing household earnings by more than \$1.2 billion.

Property development, economic renewal, business generation:

- Both VHSR and Maglev systems are predicted to have generally positive effects on property values and land development around station areas, although this type of development will not occur with the same level of intensity as that associated with many transit stations, since transit stations attract a higher amount of patronage and through-traffic than inter-city high speed rail stops. Existing land use conditions and policies, growth management initiatives, zoning ordinances and other governmental planning policies will in large part determine the form and range of such effects.

Transportation cost savings (travel time, value of time saved, total travel cost saved):

- Existing air travellers journeying on business trips along the New York State corridor would experience the greatest transportation cost savings if they would divert to using high speed rail or Maglev. Existing rail travellers on business would experience lower benefits, as a group, and existing highway users travelling on business would not save at all by diverting to high speed rail or Maglev. Transportation cost savings arise out of differences in the total of the cost of travelling by each mode, including the line haul time (in hours), and access and egress time, all valued by business travellers at rates corresponding to average hourly take-home pay, and out-of-pocket costs such as tolls, fares and parking fees.
- Among existing non-business travellers, only those travelling by air, taken as a whole, would save on total transportation costs by diverting to high speed rail or Maglev. All other non-business travellers would face higher total transportation costs by diverting to high speed rail or Maglev.

Economic and Financial Analyses

- For those existing travellers throughout the region that would benefit from diverting to high speed rail or Maglev, total transportation cost savings amount to over \$90 million in 1993 dollars. The majority of these systemwide savings is accounted for by existing business travellers (over \$68 million), with the remainder accruing to non-business travellers.
- Looking at all business trips throughout the existing corridor, the total annual transportation cost savings achieved by diverting to a VHSR/Maglev system amount to only \$16.4 million, with over \$51 million in annual savings for air travellers alone, \$9.7 million in savings for existing rail passengers, and net cost increases of more than \$39 million for passenger vehicle users who need their cars at their destinations, and \$5 million for users who do not. For the diverted auto passengers, the convenience of HSGT travel, ability to work while traveling and reduced travel time justify the increased cost.
- Looking at all non-business trips, the total annual transportation cost savings from diverting to VHSR/Maglev would be negative.

Societal, community benefits, prestige:

- A new, affordable high speed rail or Maglev system will undoubtedly improve access for the transportation disadvantaged such as the elderly, the young and even lower income groups. Access will be enhanced to emerging job markets, cultural and artistic centers, health care facilities and educational institutions. New York State will gain prestige from developing an energy-efficient and fast mode of transit, a major marketing rationale, since it conveys a state in control of its best social, business and commercial interests.
- Enhanced workplace productivity:
- Faster access to existing jobs, to emerging jobs, or better access by the unemployed to potential job markets all have an effect on workplace productivity.

Section 7
BUILDING THE FINANCIAL CASE FOR VHSR/MAGLEV
IN NEW YORK STATE

As a transportation system providing a public service much like that afforded by aviation or highway travel, high speed travel by rail generates significant and substantive benefits to the traveler and non-user alike. In doing so, it qualifies for consideration as a service worth supporting by some measure of government assistance and involvement. This can take the form of fare subsidization, government provision of right-of-way, pricing of competing modes, operational assistance or outright grants. Viewed as a business venture, another issue is whether VHSR/Maglev systems can generate enough direct revenues to attract private sector involvement. This can take on many forms, such as equity investment or development of portions of the system itself, operational responsibility, financing portions of the ongoing costs of operations and maintenance for a fee, providing the rolling stock as a demonstration of new technology, sharing of the right-of-way with other fee paying uses such as telecommunications, fiber optics, utilities or other links, etc. Our task in this section of the report examines these and other financial considerations for a VHSR/Maglev system in New York State.

INSTITUTIONAL ARRANGEMENTS

In evaluating options for financing a HSGT system, our first task was to examine the institutional arrangements and obstacles involved. This is particularly poignant for a system that requires a major

commitment of financial resources, and that has such a large potential for generating benefits. In place in the U.S. there is no operational experience with such a system, no experience with the level of (intangible) economic benefits likely to occur, and thus no clear way of assuring the public that their financial resources that would otherwise have been dedicated to meeting other public needs are being well spent. The best lessons we can draw from arise out of the operational experiences gained with systems elsewhere around the world (Japan, Germany, and France) and from the most progressed initiatives throughout the U.S.

Where there are operating systems, the Shinkansen (Japan), ICE (Germany) and TGV (France) all have a few arrangements in common: they have been developed with significant public financial assistance; the national government was critically involved in almost every phase of development; the national or federal railroad took the lead in overseeing the programs; and, finally, the largest industrial concerns were involved in building the rolling stock. Both the French and German systems have been integrated into the national (or federal) railway system, while the Japanese system operates under mixed public and private ownership. What is particularly noteworthy is the type and extent of public sector involvement in these systems.

Despite this, it is often claimed that the French National Railway (the SNCF) developed the Paris-Lyon TGV (known as the Southeast line) without government subsidies. The \$1.6 billion capital cost was raised by using SNCF funds as well as by borrowing from the private capital markets. However, the French government guaranteed the loans, provided the right-of-way, and ensured that the domestic French airline would be coaxed into reducing its air service in the corridor as soon as the southeast line went into operations. Indeed, the second TGV line (the Atlantique, opened in 1990) benefitted from the French government paying close to a third of its capital costs directly. Furthermore, the French railcar contractor, GEC Alsthom, is closely linked to the French government through partial ownership and subsidization of its operations.

While the French system was in operation, the Germans developed their own system (the ICE train) using a consortium of German government agencies (the Federal Ministry of Research and Technology), the German Federal Railway as well as several large industrial conglomerates. Most of the financial backing for the ICE system has come from the federal government itself. Even Lufthansa, the German air carrier, works closely with ICE schedules to feed passengers and freight to its domestic and international operations.

Turning to the U.S., every intercity corridor initiative involving VHSR/Maglev has been carried out locally, assuming a significant role for the private sector. While the financial responsibility for developing each system has proceeded under this assumption of a private role, the State has typically initiated the process by commissioning or sponsoring feasibility studies. Examples of sponsoring bodies include State departments of transportation, or special authorities, either existing or specially created, for the purpose of managing the overall planning for such systems. However, there have been few attempts to examine the implementation of these systems within the broader context of a national transportation system, akin to Europe's. The U.S. simply does not support an institutional set up or financial structure that is currently designed to do this for VHSR/Maglev, although certainly a nationwide structure exists and is thriving for highways and air.

We examined the initiatives in Florida, California, Nevada, Ohio, and Texas. Despite differences in circumstances and the types of agencies involved in the planning evaluation for such systems, they do have much in common. Each sponsoring agency involved was an autonomous entity, empowered to study the feasibility of VHSR/Maglev systems as well as award a concession or franchise to entities seeking to plan, design, finance, build and operate a system within its jurisdiction. Each agency, and every venture to date, have contemplated assigning a significant portion of the costs to the private sector. That is, the holder(s) of the franchise(s) or concession(s) would be expected to find the necessary capital to fund the full range of development activities for such systems. To date, not one venture has succeeded in achieving this goal, although in some cases, significant private capital has been expended (either in the form of outright cash or contributed services) on early development costs.

In almost every venture, there has been creative thinking on revenue sources other than the farebox to retire the system's debt and pay for ongoing expenses. Such sources include revenues derived from impact fees, special assessments on adjacent properties and other real estate development "capture" mechanisms, sharing of right-of-way and vendor financing of the rolling stock. In almost every case, there has been a substantial amount of doubt (or at least concerns raised) regarding the estimates of patronage, of capital costs and of operating and maintenance expenses. Almost every venture has contemplated the use of tax exempt revenue bond financing, and every proposal has called for the granting to the franchisee of some level of development rights along the corridor in question.

Historically in the United States VHSR and Maglev projects have been introduced as private ventures in search of public support in terms of legislative and sometimes financial backing. The

following is a brief description of five U.S. projects, their initial financial planning and the current changes these plans are undergoing to respond to changing legislation and financial markets.

The projects described are:

- Florida VHSR;
- Florida Maglev;
- Texas TGV;
- Ohio VHSR; and
- California-Nevada.

STATE OF FLORIDA VHSR

Following a feasibility study that examined the implementation of a VHSR system, the state legislature enacted a law (in 1984) prescribing a detailed series of steps to be followed in order to award a concession to entities seeking to develop systems in the state. The state also established a VHSR Commission, granting it authority to solicit and reward proposals to develop systems, issue tax exempt bonds as well as acquire right-of-way for station locations.

The Commission would select a technology option as well as the qualified sponsor/developer. Before the award of a franchise, the sponsor's application would have to be certified by separate state officials (the Governor and the Cabinet). Other governmental agencies would review and approve the application on environmental protection/conservation, land use policy and growth management grounds. Given the likelihood of a federal environmental impact statement required, the Federal Railroad Administration would be designated the lead agency by the Council on Environmental Quality at the federal government.

For its troubles, the franchisee would be awarded development rights in and around station areas as well as in adjacent properties. Tempted by the potential to be realized by such development, franchisees would rely heavily on real estate "value capture" income to finance the costs of developing VHSR systems. Not only could franchisees count on revenues raised from special assessment property tax surcharges along the corridor, but they could also use eminent domain to acquire property surrounding station sites.

The Florida VHSR Commission issued requests for proposals for two different projects: VHSR as well as Maglev. Under the VHSR solicitation, two proposals were received in 1988, one utilizing the Swedish steel-wheel technology and financed mostly through real estate related revenues, the other

proposing to use the French TGV and financed mostly through the farebox.

The Florida VHSR project consisted of high speed steel wheel on steel rail technology. Major project terminals included Miami, Orlando, and Tampa. The total of 314 miles of rail had an estimated construction value of \$12.6 billion. Travel time was estimated at 2:40:00. The estimated travel speed is 185 mph. Initial ridership projections were 2.4 to 5.9 million passengers per year, drawing from a strong tourist trade.

The original Florida financing scheme developed in April 1986 relied on a mix of public and private investment, including equity investment, real estate development, and farebox revenues as non-public mechanisms. The total private financial burden was 28 percent of the estimated \$12.6 billion project cost. The thirty-year net operating revenue estimate was a negative \$339 million, requiring substantial public support for funding. Included in the public financing mechanisms were tax increment financing (16 percent), impact fees (17 percent), and special assessments (39 percent). The ensuing downturn of the real estate market and instability of the financial markets greatly weakened the justification of the project's development-backed financing.

The developers for the project have reassessed the financial plan. An even greater degree of public backing is required with the use of private investment around station locations. Possible solutions to reducing total project costs include utilizing free right-of-way along Interstate Route 4 between Orlando and Tampa. The amount of federal funding available through the I-4 improvement program or through the Intermodal Surface Transportation Efficiency Act (ISTEA) and High Speed Rail Development legislation has not been determined.

The Florida Maglev Demonstration project consisted of a magnetic levitation rail line from the Orlando airport to International Drive in Orlando, Florida. The total project length is 14 miles at an estimated construction cost of \$450 to 650 million. Top design speed is 250 mph with a travel time of 0:04:00. Estimated ridership is 6.5 to 8.5 million passengers per year.

Separate from the Florida VHSR project described above, the Florida Maglev project has progressed along a different financial course. This project received certification to proceed in June 1991 based on a preliminary financial plan that relied mostly on private investment. Total project costs for this Maglev demonstration project were estimated to be at least \$622 million. The majority of the financing was to emanate from three sources:

- Farebox Revenues (estimated to be sufficient to cover the annual operating and maintenance costs);
- ISTEA Appropriations - Right-of-way and construction funds were to be partially funded through various funding programs from ISTEA; and
- Private Capital - the remainder of funding was to come from three equally shared private capital investment groups.

The federal participation portion of the project, \$97.5 million or approximately 15 percent, authorized by ISTEA, was allocated from the Federal Highway Trust Fund. The balance of the financing was expected from a Japanese banking group and shared equally through a triad of banking groups from Germany, Japan, and the United States.

As the first state to actually receive proposals to develop largely privately financed VHSR systems in the U.S., Florida's experiment has not succeeded to date primarily because of the over-reliance on real estate related revenues as a means of financing the costs of development. Particularly as the state's real estate market expansion came to an end in the late 1980's, the financial feasibility and viability of the project was left in doubt. In addition, the unfavorable conditions at the capital markets, the opposition by Florida officials to any public assistance or financing for a system and the presence of overwhelming competition from air carrier traffic have each added to the complications of implementing a system, and little further progress will be made until circumstances change significantly. It is useful, however, to draw some inferences from the Florida experiment for the purposes of this study.

TEXAS VHSR

Texas created its own VHSR Authority by statute in 1989 following a feasibility study performed by the Texas Turnpike Authority examining travel demands between San Antonio, Dallas and Houston. At the outset, Texas officials decreed that public funds not be used to develop such a system, preferring instead the benefits of private capital. The Authority issued a request for proposals in January 1991 and received two responses, one using the TGV and the other using the ICE technologies. Each sponsor remitted a non-refundable fee of one half million dollars, which the Authority used to reimburse the state's costs to that point such that no state monies would be drawn upon. The Authority then awarded a franchise to a consortium proposing to use the TGV VHSR

trains for the initial 250-mile trip from Houston to Dallas-Fort Worth.

The consortium is in the process of performing a patronage forecasting study and scoping work for the federal environmental impact statement, all at its own cost. Indeed, the entire development costs for the (now) \$7.5 billion system are proposed as being the consortium's responsibility, with no public funds committed. Opposition to the project is fiercest from Southwest Airlines, a low cost air carrier serving the major metropolitan areas to be covered by the system.

The Texas TGV project provides VHSR service to three major destinations: Fort Worth/Dallas, Houston, and San Antonio. Total length of track is 620 miles, 244 miles of which represents the distance from Dallas to Houston, with the remaining 236 miles covering the distance between Dallas and San Antonio. With a steel wheel on steel rail design speed of 185 mph, travel time from Dallas to Houston is 1:30:00, or 5:35:00 to travel the entire triangle. Project costs range from \$2.0 billion for the Dallas to Houston line to \$6.8 billion for the entire project.

The original financing plan for the Texas TGV project anticipated a 24-year financing period during which the project financing would come from:

- Farebox revenues (82 percent);
- Private equity participation (9 percent);
- Parking fees (4 percent); and
- Mixed use of right-of-way, telecommunication lines, etc. (5 percent).

The entire project proposal is by private investment: no state public funding was allowed due to the Texas legislation. The focus to date has been to target a service corridor that has the potential to generate sufficient operating revenue over the long term to provide an adequate rate of return for private investment. The basis for the fare structure in the Texas market is 100 percent of the airline fares. Any undercutting of the airline fare structure is thought to be detrimental to both the airline industry operations and the success of the TGV.

To this end the project scope has been redefined to include only two legs of the original triangle envisioned; Dallas to Houston and Dallas to San Antonio. The Houston to San Antonio corridor is still under study. The project financing currently is being evaluated to reduce capital costs and carefully phase project expenditures. The financing plan consists of three separate equity participation vehicles, staged to coincide with the phases of project development and construction

and the varying degrees of associated risk. Total project costs are estimated to be \$6.5 to \$6.8 billion for approximately 480 miles of track.

Phase I of the project consists of detailed planning and environmental impact statement. This phase is expected to cost \$50 to \$60 million and is to be financed through high risk, founder's equity. This founder's equity is private capital invested in the project at a point where the project's likelihood of continuing to the next phase is very risky. For this very early and risky investment, private participants require substantial returns on investment. This earliest form of equity participation (preferred stock) would carry the highest priority for dividend payments.

Phase II of the project consists of preliminary engineering in sufficient detail to issue design/build contracts. This phase is expected to cost \$100 to \$120 million and is to be financed through venture capital equity. The financing for the third and fourth phase of the project, the construction and early operation phases respectively, is expected to be a mix of publicly-placed debt and equity. The proposed ratio of debt to equity for the publicly traded corporation is three to one. The debt totalling \$5.9 to \$6.1 billion is to be a mix of two-fifths private activity (tax exempt) bonds backed by a private letter of credit and of three-fifths taxable project revenue bonds. By the time the construction phase of the project has been financed, the founder's equity and the venture capital equity are expected to be fully integrated into the open market offering the early investors a rate of return without limitations. The franchise agreement is for fifty years and is not tied to the repayment of debt. Debt issue duration is to be only fifteen years due to the expensive nature of private letter of credit backing. The franchise long term financing (in place after five to seven years of operation) is to operate almost like a utility financing in the public investment community with rates of return based on payments of earnings.

As the project is still very much active, it is too early to draw conclusions or inferences from its successes or failures, regardless of how they are perceived. It does seem inconceivable, however, that the project will be able to raise in excess of \$6 billion in long-term construction financing through the issuance of farebox backed debt.

OHIO VHSR

Planning for VHSR in Ohio commenced with the formation of the Ohio Rail Transportation Authority in 1975. Since that time, several technical studies have examined the feasibility of implementing a system throughout the state. The studies recommended a 600-mile system connecting 13 cities with links to Detroit and Pittsburgh at a projected cost of \$8 billion (1982 dollars). In 1983, the state of Ohio created a 15-person VHSR Task Force, the members of which were appointed by the Governor. The Task Force was charged with developing a more conservative VHSR plan with lower capital costs. Its findings were presented in 1985, and involved an initial system in the 3-C corridor (Cleveland, Columbus, and Cincinnati) using VHSR technology with maximum speeds of 170 miles per hour or higher. Expected capital costs for the now reduced corridor were at \$2.1 billion (1985 dollars), with significant economic benefits accruing to the state.

Based upon the Task Force's recommendations, the Governor recommended to the legislature that the state have a VHSR authority to develop a financial and systems operational plan for the system. The Ohio VHSR Authority solicited proposals from the private sector to develop a plan to finance, design, build and operate the system in the 3-C corridor in 1989, and the Ohio Railway Organization (ORO) was selected to perform this service at no cost to the state in 1990. ORO prepared an action plan to implement a VHSR passenger system in late 1991, at its own expense, and a Revised Plan was submitted in late 1992.

The Ohio VHSR project links Cleveland, Columbus, and Cincinnati for an estimated construction cost of \$3.1 billion. Design speeds for the steel wheel on steel rail project are 150 mph to 185 mph. Travel time between Cleveland and Columbus is 1:08:00 and between Columbus and Cincinnati is 1:34:00. Expected ridership is 2.2 million passengers per year.

According to the Implementation Plan for VHSR in Ohio, dated June 1992, the project farebox revenues alone are not sufficient to support the financing or to permit a purely private project. The planned approach for this project is to combine public and private finance concepts: "Substantial public subsidies will be required if the public purposes served by the rail corridor are to be met." Proposed financial mechanisms include:

- Federal financial assistance programs;
- Tax exempt financing;
- Private debt; and

- Private equity.

For the early phase of the project (planning, design and demonstration) the majority of financing is expected to be from federal programs including:

- ISTEA High Speed Ground Transportation Technology Demonstration Program;
- ISTEA High Speed Ground Transportation Research and Development Program;
- ISTEA Demonstration Turnkey Projects Program; and
- ISTEA National Magnetic Levitation Prototype Development Program.

No state assistance is expected during Phase I. The proposed financial plan for the project does note the possible use of state issued bonds backed by sales or excise tax revenues to assist financing preconstruction activities. Additional potential sources of revenue in the pre-construction phase of the project, identified but not elaborated upon, include vendor participation and/or sweat equity in return for concessions in specification of parts and equipment in the final system design parameters.

The proposed debt financing for Phase II, Construction, is a public ownership structure with tax exempt debt issuances. The goal of the project's financing plan is to combine the public debt financing with private capital in rolling stock, operation of system components and some construction activities. In terms of debt financing, the Railroad Revitalization and Regulatory Reform Act of 1976 was amended by ISTEA to facilitate loan guarantees. The use of these funds is to be balanced with the provisions for using 85 percent U.S.-produced and manufactured facilities and equipment, unless certain conditions are present, e.g., use of U.S.-produced parts and materials increases the total project costs by 25 percent, or that the requirement would result in a violation of an international trade agreement. One hindrance to tapping these funds is a legislative matter that is yet to be addressed by Congress: no authority has been given to the Federal Railroad Administration (FRA) to make appropriations for these funds. Additional funding programs sought by the financing plan include the Federal Transit Administration funds and the Surface Transportation Program funds. State issue debt financing is expected to comprise the majority of the construction phase financing. The legalities and Internal Revenue Service ruling on taxable and tax-exempt funding have yet to be addressed. Contribution of right-of-way by the State of Ohio is mentioned in the project's financing plan as a potential method of decreasing project costs. In terms of private participation to financing, private contribution of right-of-way also is identified. Cross-border leasing for rolling stock carries tax advantages that are captured by the project through reduced capital expenditures.

CALIFORNIA-NEVADA

The effort by the states of California and Nevada to develop a VHSR system financed entirely by private money between Los Angeles and Las Vegas (a project known as the "Gambler's Express" for appropriate reasons) has resulted in the concessionaire withdrawing from the project entirely. The California-Nevada Super Speed Ground Transportation Commission first met in 1988 and solicited proposals in 1990. Only one group submitted a proposal in 1990 and was awarded conditional franchise rights to privately construct and operate a \$5 billion Transrapid Maglev system between Anaheim and Las Vegas. In late 1991, the franchisee withdrew from the project, citing the conditions at the capital markets, the inability to secure sufficient development funds to proceed, and reacting to the governor of California's veto of legislation extending the Commission's term of operations. The proposer concluded that the lack of public sector support for the project, particularly the lack of state planning and regulatory assistance, would render its proposal highly risky.

Looking at a hypothetical proposal for this corridor, a privately financed proposal would have to incur significant development costs before any final approvals of the project are made. Under the bi-state Commission's charter, the private sponsor would have to pay for all of the environmental studies and for the costs of review and approval by state and federal agency staff, and estimates have run up to the \$50 million range for such an effort. Further at risk would be the sponsor's costs for preliminary and final engineering and design, patronage studies, financial costs of operation and the costs of any private placements of capital. Given such formidable obstacles, it is not surprising that the effort in California-Nevada has so far failed, despite relatively favorable project economics.

The Los Angeles to Las Vegas (California-Nevada) VHSR project would utilize the steel wheel on steel rail technology to attain design speeds of 186 mph or would utilize the magnetic levitation technology to attain design speeds of 300 mph. Total travel time, depending on the technology selected, is about 1 hour for the 260 mile line. Project costs range from \$2.5 to \$3.7 billion. Annual ridership was estimated at 3.8 million passengers.

The California-Nevada project, as originally proposed, consisted of 1 percent private equity and 99 percent farebox revenue. The expected issuance of \$7.8 billion of tax exempt debt was combined with \$1.0 billion of taxable commercial debt, and \$970 million of equity, to finance the construction and early operation phase of the project. Over a thirty year franchise agreement, the farebox revenue was expected to total \$86.3 billion, covering annual operation and maintenance, debt service

and a rate of return for the equity participation.

This project has yet to be developed further than the proposal stage due in part to the changes in the world financial market and the lack of sufficient development capital. Alternate influences that have been proposed as contributing factors in the project's demise include an unrealistic expectation of the private sector's role in the development of VHSR. Specifically, the right of eminent domain and sovereign immunity were obstacles insurmountable to this project. Overcoming environmental and other regulatory approvals was another area where the private developer received no assistance.

Cost estimates of up to \$40 to \$50 million were expected to be incurred prior to any acknowledgement of environmental or other permit clearance. This funding was expected to be strictly high risk venture capital. All these expenses were to be incurred regardless of the political stability or backing for the project. It is still thought that the corridor is economically viable for a VHSR project, but the development of the project as a strictly private enterprise is not a reality.

Figure 7-1 summarizes the current financial status of other U.S. high speed ground transportation projects as described above. The Ohio Project has not been illustrated because its actual financing plan is still uncertain at this time.

FLORIDA HIGH SPEED RAIL

TEXAS TGV

FLORIDA MAGLEV

CALIFORNIA - NEVADA

Figure 7-1. Current Financial Status of Other U. S. VHSR/Maglev Projects.

A FINANCIAL APPROACH FOR NEW YORK'S VHSR/MAGLEV SYSTEM

The achievements and failures of the VHSR initiatives in the U.S. and abroad provide critical lessons from which a viable and realistic financial approach for the State of New York can be molded. The first task is to determine the financial goals for the system, ensuring that adequate funds are available for planning, design, marketing, development as well as construction and operations. The next task is to assess the use of federal and state financial assistance, programs and grants, determine the availability of and constraints on the use of tax-exempt debt, and investigate the potential role of private equity, perhaps in the form of vendor financing for the rolling stock, and/or debt.

Concurrent with these tasks, we must examine some possible operators of the system, and potential roles for various public agencies, ranging from development, to marketing, to regulation and system procurement. The financial approach to the system depends on the ownership structure envisaged.

A "New York State HSGT Authority" would permit public ownership financed by the use of tax-exempt debt. Overall, the use of tax-exempt municipal bonds for major infrastructure projects represents an attractive financing scenario for any system. Requiring jurisdictional cooperation and coordination, tax-exempt bonds are most often associated with public financing structures but are, nevertheless, available to the private sector.

On the other extreme, part of the system could be financed using commercial bank loans, bearing market interest rates. Although unlikely in reality, we will carry forward the private financing approach as an alternative to be evaluated at this point. Whether a franchise can be awarded by New York State for private development, construction, operation and maintenance of the system is not clear. Substantial financial, legal and institutional constraints would be brought to bear. However, private franchising for a portion of the system is consistent with an overall federal initiative to harness the leveraging power of private capital, as recently confirmed by an Executive Order of the President.

FEDERAL ASSISTANCE

Pre-Construction Phase

It is readily apparent that substantial government or public investment, particularly federal and state grants, would be necessary and appropriate for the up front planning, design, environmental and demonstration activities involved with implementing the system. A nationwide high speed rail or Maglev initiative is the type of commitment that is often envisaged by proponents of such systems. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the pending High Speed Rail Development Act of 1993, for example, contained several sources of federal assistance. Of course, although authorized for future expenditures, ISTEA is subject to the Congressional budgetary process in terms of appropriations. It is not entirely clear, therefore, that programs and grants will be made available to the extent that they are authorized. However, for the purpose of preliminary planning for financing the development of the system, several sources can be counted upon:

- ISTEA set up a high speed ground transportation technology demonstration program. Authorized up to \$50 million, the program provides that the Department of Transportation award contracts and demonstration grants for studies to determine the contributions that VHSR systems can make on efficient intercity travel;
- ISTEA established a high speed ground transportation research and development program. Authorized up to \$25 million, the program enables the Department of Transportation to enter into cooperative research and development as well as funding agreements with private parties to advance basic high speed technologies;
- ISTEA created the National Magnetic Levitation Prototype Development Program, authorizing up to \$725 million in federal funds be awarded for the development, design and construction of a prototype Maglev system. It is not clear whether or not these funds can be made available for a more conventional steel wheel technology, given the delay foreseen in implementing a Maglev demonstration system in the U.S.; and
- ISTEA authorizes the Department of Transportation to approve at least two turnkey demonstration projects for new transit systems. A "turnkey system project" is defined as a "project under which a [federal assistance] recipient contracts with a consortium of firms, individual firms or vendors to build a transit system that meets specific performance criteria

and which is operated by the vendor for a period of time".

- The High Speed Rail Development Program proposes a minimum 50-50 Federal-State match program for high speed rail programs.

Construction Phase

For the construction phase of the system, ISTEA amended the loan guarantee provisions of the Railroad Revitalization and Regulatory Reform Act of 1976 with potentially substantial implications for HSR/Maglev in New York State. Under the amended program, federal guarantees can be authorized specifically for the financing of HSR systems. The law allows the Department of Transportation to guarantee obligations of a public or a private railroad, including (as a result of ISTEA) debt incurred to establish HSR facilities and equipment. HSR is defined as a rail system "reasonably expected" to reach speeds of in excess of 125 mph. By this definition, both the VHSR and incremental improvement options described in this study would qualify. No more than a billion dollars of obligations can be outstanding at any time. Also, any HSR system, including facilities and equipment, financed with a federally guaranteed loan must have a U.S. manufacturing content of at least 85 percent, unless the Department of Transportation finds that:

- Such a requirement would be inconsistent with the public interest;
- Items of satisfactory quality could not be produced in the U.S. in sufficient quantities;
- The requirement would increase the cost of the facilities by more than 25 percent; and
- The requirement would result in a violation of the obligations of the U.S. under an international trade agreement.

Even though ISTEA has been promulgated, the Federal Railroad Administration has not appropriated at the present time any budget to enter into loan guarantees. This may change.

Other provisions of federal law could help defray the costs of right-of-way acquisition and grade crossing hazards for VHSR, Maglev or incremental improvements. ISTEA authorizes that, where sufficient land or airspace already exists within the publicly acquired right-of-way of any federally aided highway to accommodate passenger, commuter or VHSR, magnetic levitation systems and mass transit facilities, the Department of Transportation can provide for the state making such land, airspace or rights of way available, with or without charge, to a publicly (or privately) owned company, if such an accommodation will not adversely affect automotive safety.

Two provisions of federal law allow the use of federal funds to eliminate the hazards of railway crossings. ISTEA contains a provision authorizing the U.S. Department of Transportation to set aside up to \$5 million of Surface Transportation Funds in each year to be used to eliminate hazards in railway crossings, in up to five rail corridors. The selected corridors must include rail lines where speeds to 90 mph are occurring or can be reasonably expected to occur in the future. Federal law also allows sums apportioned to the states under the federal highway program to be spent for the entire cost of constructing projects to eliminate the hazards of rail crossings, including grade separations, reconstruction of existing grade crossing structures and relocations of highways to eliminate grade crossings, or, where the cost is lower, relocation of the railway. It is unclear whether this provision applies to newly developed rail lines.

Other provisions under ISTEA include the establishment of a new federal matching program for the use of the Highway Trust Funds under the Surface Transportation Program (STP). STP funds are flexible and can be used for, among other things:

- Capital costs for transit projects eligible for assistance under the Federal Transit Act. Although the governing statute of the FTA (formerly UMTA) does not specify clearly what projects fall within the FTA's authority, it does not fund rail services that are primarily of an intercity nature. However, the FTA has approved federal assistance to commuter rail projects and to the commuter service portions of larger rail systems;
- Transit safety improvement programs, hazard eliminations, and projects to mitigate hazards caused by wildlife and railway-highway grade crossings;
- Transit research and development and technology transfer programs; and
- Surface transportation planning programs.

FTA could interpret its statute to allow it to direct STP funds toward HSR projects even though it is not completely clear what rail systems are indeed eligible for assistance under the Federal Transit Act. But this is speculative. However, ISTEA does seem to allow for federal funding of even the non-commuter portions of rail lines. By amending the Federal Transit Act to make the terms "transit," "public transportation" and "mass transit" synonymous, ISTEA defines these terms to include publicly (or privately) owned rail facilities without reference to the geographical area served. It is the reading of several attorneys who have tracked the legislative history of ISTEA that

conventional rail facilities be considered for STP funds. Clearly, it may be in New York State's interests to designate HSR as a recipient of available federal assistance that would act as a source of construction financing, providing a layer of federal equity to supplement the significant debt that is foreseen.

The High Speed Rail Development Act of 1993 together with the Clinton Administration \$1.3 billion national High Speed Rail Development Program offer significant opportunities for Federal participation in New York States HSGT implementation programs.

Considering that the National Highway System is typically improved with public funding with the Federal government paying 80 percent to most regional improvements and 90 percent for improvements on the Interstate Highway System, a Federal contribution of 75 percent of the capital costs of HSGT systems is in line with its support of other modes of transportation.

STATE ASSISTANCE

There are two options for State assistance for the HSGT system: the State can issue tax exempt bonds that are backed by a dedicated revenue stream, or the State can issue general obligation bonds, backed by the State's full faith and credit. Dedicated revenue sources can generate dollars even before the construction of the high speed rail or Maglev system and thus can help defray the initial costs of project development, and serve as backing for the issuance of bonds. We examined other sources of New York State funds including economic development funds.

Since the construction and operation of the HSGT system in New York State is expected to generate significant economic benefits statewide as well as regionally, state and/or local governmental units may find it desirable to reduce the total land acquisition costs of the system by donating parcels. Such donations of acreage must, of course, be in accordance with applicable statutes and laws, and in conformity and compliance with land-use plans.

SYSTEM REVENUES AND FARE STRUCTURE

Clearly, a major test of the financial feasibility and viability of a HSGT system in New York State is the ability of the revenues generated from its operations to cover, first, operating and maintenance costs, and then some portion of the capital costs through debt repayment. A corollary issue, and no less important, is the fare levels and fare structure that are needed to achieve either or both of these goals. A low fare attracts higher patronage, resulting in greater user benefits such as reduced travel times, but renders the financial viability of a system less likely. Thus, an important issue is what the fare structure should try to accomplish. For the purposes of this study the financial analysis was made at a fare structure which developed maximum system revenue. This was found to be roughly 220 percent of existing rail fares for the Maglev case and 300 percent of existing rail fares for the VHSR case.

Many feasibility studies on HSR/Maglev have assumed fares approximating the average undiscounted air fare in several markets, since most HSGT passengers would be attracted from air travel. It is very difficult to predict how the airlines would react to the introduction of a competing mode (although experience suggests that the larger carriers will be able to cross-subsidize any route, at least in the short run, to capture or maintain their patronage), and the situation is further complicated by the fact that airlines use "yield management" techniques or multiparty pricing. As a result, full-fare coach passengers may pay much more than the average rate per mile whereas discounted ticket passengers pay much less. To better compete with the airlines on the basis of fare alone, HSGT operators should engage in the same form of price discrimination.

In general, however, there are secure grounds for expecting public sector subsidization of the fare levels for HSGT systems. It is a fundamental principle of microeconomic analysis that the socially efficient price of a good or service should be set at a level equivalent to the marginal or incremental cost of serving another user. However, many capital-intensive transportation services such as rail facilities are subject to increasing returns to scale over a range of service, such that the incremental cost of serving an additional passenger are lower than the average costs of serving all users. In other words, it does not cost a rail operator much more to service his fiftieth user than his forty-ninth, as long as there is room on the train. If the rail fare were to be set at or near marginal costs, the system would operate at a significant loss. Yet if the rail fare were to be set at a break-even level or profit-making level, the rail system would be underused relative to its capacity. Therefore, public support equal to the system's losses under marginal cost pricing would ensure efficient pricing and use of the system.

PRO FORMA FINANCIAL ANALYSIS

Tables 7-1 and 7-2, and Figure 7-2 summarize the annual revenues estimated to be derived from the farebox alone for four HSGT alternatives at a fare structure which generates maximum system revenue. As described in Section 3, this is roughly equivalent to 220 percent of existing rail fare for Maglev and 300 percent existing rail fare for the VHSR and incremental options. Not surprisingly, the majority of the system revenues are derived from business travelers. These tables also illustrate the revenue bonding capacity of the system's revenues alone, that is, the amount of a transportation revenue bond that can be issued based upon the amount of annual farebox revenues alone, without regard to coverage ratios. For example, in 2010 a Maglev system yielding over \$497 million revenues annually (in 1991 dollars) can be used to repay an issued loan of over \$6.2 billion over 30 years, assuming a tax-exempt debt issue carrying a 7 percent interest rate, and so on.

Tables 7-3 through 7-6 summarize our work in estimating the total system costs of construction as well as annual operations and maintenance for both a steel wheel high speed rail alternative and a Maglev system.

Construction and operation cost estimates for the high speed rail option were calculated only for the moderate steel wheel alignment, an alternative more expensive to implement than would be expected for the VHSR Baseline case and less expensive than expected for the VHSR Aggressive case. Cost estimates produced for the incremental option were not as detailed as for the other options, resulting in a range of \$1.5 to \$2.0 billion for construction. Because improving the performance of the existing rail system will involve phased construction with uncertainties with regards to the final level of performance achieved, as well as public acceptance of a fare structure designed for maximum revenue, financial Pro Forma for this option were not developed.

Cost estimates for right-of-way acquisition were roughly estimated at \$400 million for the VHSR and Maglev alternatives. Right-of-way costs can not be accurately estimated unless specific alignments are chosen; estimates are additionally dependent on both the real estate market conditions at the time of construction, and the indeterminate price Conrail might require for the lease or purchase of rail rights-of-way currently under its ownership.

Table 7-1. Summary of System Revenues - 1991.
(in thousands of 1991 dollars)

Revenues
1991

	<u>HSR Baseline Alignment</u>	<u>HSR Aggressive Alignment</u>	<u>Maglev Aggressive Alignment</u>	<u>Incremental Option</u>
Business Travelers diverted from:				
Air	\$52,658	\$85,420	\$127,108	\$66,226
Rail	\$14,793	\$18,112	\$21,686	\$18,500
Auto (car needed at destination)	\$33,928	\$37,312	\$42,641	\$32,205
Auto (car not needed at destination)	\$8,810	\$9,572	\$10,726	\$8,904
Total for all Business Travelers:	\$110,189	\$150,416	\$202,161	\$128,835
Non-Business Travelers diverted from:				
Air	\$6,526	\$13,081	\$32,542	\$8,454
Rail	\$383	\$623	\$1,372	\$546
Auto (car needed at destination)	\$58,052	\$62,064	\$67,035	\$59,608
Auto (car not needed at destination)	\$54,402	\$57,971	\$62,386	\$55,790
Total for all Non-Business Travelers:	\$119,363	\$133,739	\$163,335	\$124,399
Total for all Diverted Travelers	\$229,553	\$284,155	\$365,495	\$253,233
Total for all Induced Travelers	\$10,825	\$23,833	\$67,277	\$14,855
TOTAL FOR ALL TRAVELERS	\$240,377	\$307,988	\$432,772	\$268,089
BONDING CAPACITY FROM REVENUES Assuming 7% Interest...				
over 20 years	\$2,546,562	\$3,262,830	\$4,584,793	\$2,840,134
over 30 years	\$2,982,854	\$3,821,837	\$5,370,286	\$3,326,722

Table 7-2. Summary of System Revenues - 2010.
(in thousands of 1991 dollars)

Revenues
2010

	<u>HSR Baseline Alignment</u>	<u>HSR Aggressive Alignment</u>	<u>Maglev Aggressive Alignment</u>	<u>Incremental Option</u>
Business Travelers diverted from:				
Air	\$56,888	\$92,362	\$129,571	\$70,489
Rail	\$18,386	\$22,466	\$21,793	\$20,043
Auto (car needed at destination)	\$36,068	\$39,695	\$37,836	\$37,437
Auto (car not needed at destination)	\$9,368	\$10,185	\$9,314	\$9,679
Total for all Business Travelers:	\$120,710	\$164,708	\$198,514	\$137,649
Non-Business Travelers diverted from:				
Air	\$7,075	\$14,201	\$37,779	\$9,172
Rail	\$488	\$797	\$14,249	\$587
Auto (car needed at destination)	\$61,634	\$65,941	\$72,188	\$63,304
Auto (car not needed at destination)	\$57,779	\$61,612	\$65,356	\$59,268
Total for all Non-Business Travelers:	\$126,977	\$142,551	\$189,572	\$132,331
Total for all Diverted Travelers	\$247,687	\$307,259	\$388,086	\$269,980
Total for all Induced Travelers	\$11,680	\$25,771	\$108,943	\$15,838
TOTAL FOR ALL TRAVELERS	\$259,367	\$333,030	\$497,029	\$285,818
BONDING CAPACITY FROM REVENUES Assuming 7% Interest...				
over 20 years	\$2,747,743	\$3,528,119	\$5,265,531	\$3,027,960
over 30 years	\$3,218,502	\$4,132,577	\$6,167,652	\$3,546,728

Figure 7-2. Annual System Revenues by Sources - 2010.

**Table 7-3. Summary of Annual Operations and Maintenance Costs -VHSR
(1993 dollars)**

Item Description	Unit cost	Cost
Personnel Costs		
Administration		8.8
Transportation		13.0
Engineering/Maintenance		24.0
Total Personnel Costs		\$45.8
Material Costs		
Equipment Maintenance		13.9
Depot Maintenance	4.4	
Repair Shop	3.6	
Trailer Rebuilding/Refurbishment	5.9	
Maintenance of Way	9.6	17.0
Structures	1.2	
Track	7.0	
Signaling	3.2	
Communications	0.3	
Catenary/Power	2.9	
Buildings/Station	0.3	
Drainage/Roads/Fences	2.0	
Electric Power		9.9
Other Costs		10.2
Contract Services	3.0	
Station Cleaning (Contracts)	0.5	
Station Consummables	0.4	
Commissions - Travel agents	2.0	
Train Cleaning supplies	0.3	
Advertising/Promotion	1.5	
Insurance	2.5	

Table 7.3 Continued		
Item Description (cont.)	Unit Cost (1993\$)	Cost (1993\$)
Administration Consumables	0.3	
Sales Staff Consumables	0.1	
Total Material Costs		\$51.0
Total Annual O&M Costs		\$96.8

**Table 7-4. Detailed Capital Costs for VHSR Technology
(1993 Dollars).**

Cost Element	Unit cost	Cost
Right of Way (Working Estimate)		\$400,000
Construction Costs		
Trackwork	1,833,500	
Roadway Preparation	161,200	
Structures	1,089,200	
Fencing	115,600	
Crossing Protection	0	
Yards/Shops & Way Stations	51,700	
Stations & Admin. Bldg	64,600	
Electrification	999,500	
Aerial Utility Relocation	22,600	
Signalization	285,500	
Communications	78,500	
Subtotal Construction Costs		\$4,702,000
Rolling Stock		\$326,400
Subtotal		\$5,428,400
20% Contingency	1,085,700	
SUBTOTAL (w/20% contingency)		\$6,514,000
ENGINEERING & MANAGEMENT COSTS		\$905,100
TOTAL COSTS		\$7,419,200

**Table 7-5. Summary of Annual Operations and Maintenance Costs - Maglev
(1993 Dollars).**

Item Description	Unit cost	Cost
Personnel Costs		
Administration		8.8
Transportation		12.7
Engineering/Maintenance		17.9
Total Personnel Costs		\$39.4
Material Costs		
Vehicle Maintenance		15.4
Maintenance of Way		19.5
Guideway	5.7	
Command & Control System	1.9	
Power System	9.6	
Stations/Buildings	0.8	
Maintenance/S&I Facilities	1.5	
Energy		15.8
Other Costs		10.6
Contract Services	3.6	
Station Consumables	0.4	
Commissions - Travel Agents	2.0	
Train Cleaning supplies	0.3	
Advertising/Promotion	1.5	
Insurance	2.5	
Administration Consumables	0.3	
Sales Staff Consumables	0.1	
Total Material Costs		\$61.3
Total Annual O&M Costs		\$100.5

**Table 7-6. Detailed Capital Costs - Maglev Technology
(1993 Dollars).**

Cost Element	Unit cost	Cost
Right of Way (Working Estimate)		\$400,000
Construction Costs		
Guideway	7,725,000	
Roadway/Parking Lots	8,800	
Fencing	15,100	
Crossing Protection	0	
Yards & Shops	103,100	
Service and Inspection Facilities	154,500	
ROW Maintenance Centers	21,400	
Stations and Admin. Bldg.	324,500	
Power System	2,689,200	
Command/Control System	654,200	
Subtotal Construction Costs		\$11,695,800
Vehicles/Special Equipment		\$277,200
Subtotal		\$12,373,000
20% contingency	2,474,600	
Subtotal w/ 20% contingency		\$14,848,000
Engineering and Management Costs		\$2,155,100
TOTAL COSTS		\$17,003,000

In comparing total system costs to annual system revenues for each technology, all (one-time) construction costs had to be converted to yearly payments. This annualization was accomplished in two different ways: first, under a public financing scenario, assuming a tax-exempt bond issue at seven percent interest over a 30 year term at 1.3 times debt coverage; and then under a private financing scenario, assuming eleven percent interest, also over a 30 year term at 1.3 times debt coverage.

For revenues, we used the 1991 farebox revenue figures estimated by CRA (refer to Tables 7-1 and 7-2), added to the estimated revenue from freight of \$231.0 million per year (refer to Section 3: Market Analysis). The CRA figures, originally calculated in 1991 dollars, were updated to 1993 dollars (to match the construction and operating cost estimates) using an annual inflation factor of 3.6 percent.

Our findings, assuming no federal or state assistance, (shown in Tables 7-7A through 7-8C) are as follows:

- A. A high speed rail system (using steel wheel technology) will involve over \$8.04 billion (1993 dollars) in capital costs, including the cost of construction, right-of-way, rolling stock and contingencies. Annual operating and maintenance costs for such a system will run over \$96.8 million. Assuming a transportation revenue bond issued at a tax-exempt rate of 7 percent for 30 years and a debt coverage ratio of 1.3, the total annual system financial needs are on the order of \$968.1 million. Yet revenues derived from passenger and freight services yield only \$489.0 million annually for the HSR Baseline alignment, and \$561.6 million for the HSR Aggressive alignment, resulting in annual revenue shortfalls of \$479.1 million and \$406.6 million, respectively.
- B. Considering the financial feasibility of private involvement for a steel wheel high speed rail system, assuming that the costs of construction and operation are identical to those under public ownership, control, and procurement (although there might be significant savings by having a private operator avoiding New York State's Wicks Law by avoiding the need to separately procure major portions of the system's construction), and a private, taxable loan carrying an interest cost of 11 percent, with a 30-year term and a debt coverage ration also of 1.3, the total system's debt and expense costs amount to over 1.33 billion dollars annually. With revenues assumed to be the same as those under public ownership, annual revenue

shortfalls approach \$839.1 million annually for VHSR Baseline, and \$766.5 million annually for HSR Aggressive.

- C. For a Maglev confined to the New York State corridor, under the public financing scenario, total annual system debt and expense costs amount to \$2.1 billion in 1993 dollars; annual system revenues are estimated at \$765 million, resulting in an annual funding shortfall of \$1.34 billion.

Regional weighted fare structure based on passenger miles

Ridership and revenues are maximized by a system that has regional extensions. Projections show that annual passenger miles within the corridor could be increased from 1 billion to 3.1 billion with system extensions to the west, south, and east. A fare structure based on trip mileage (similar to existing rail), which allows for fare distribution based on passenger mileage, might therefore be expected to provide passenger farebox revenues of more than \$1.5 billion attributable to the Empire Corridor. With modest Federal assistance in construction financing, under such a scenario the New York State HSGT system could likely cover all costs including capital recovery.

- D. Considering Maglev under the private financing scenario, the system cannot recover sufficiently its capital and operating costs through freight and passenger fares, with an annual revenue shortfall of \$2.21 billion.

Table 7-7-A. NYS VHSR Revenue Bond Financing Pro Forma Assumptions (1993 dollars).

USES OF FUNDS	THOUSANDS OF DOLLARS
Design and Engineering Management	\$ 905,117
Right-of-Way Acquisition	\$ 400,000
Rolling Stock	\$ 326,400
Construction Capital Costs	\$4,702,029
SUBTOTAL	\$6,333,546
20% Contingency	\$1,085,686
SUBTOTAL including 20% contingency	\$7,419,232
Capitalized Construction Interest Expense	\$ 620,668
TOTAL SYSTEM CAPITAL COSTS	\$8,039,899
Annual Operations & Maintenance Costs	
Labor Costs	\$ 45,800
Materials Costs	\$ 51,000
TOTAL ANNUAL O&M EXPENSES	\$ 96,800
ANNUAL SOURCES OF FUNDS	
VHSR Baseline Farebox Revenues	\$ 257,996
VHSR Aggressive Farebox Revenues	\$ 330,562
Freight Revenues*	\$ 231,000

*Freight revenues are based on the following assumptions:
the HSGT system is mature; it extends throughout the Northeast and west to Chicago; and
shipping and sorting facilities are in place at the various destinations.

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Table 7-7-B. NYS VHSR Bonding Needs and Coverage Ability of Farebox Revenues.
(1993 dollars)

ANNUAL USES OF FUNDS	Thousands of Dollars
Total Sytem Capital Cost of Debt	\$ 647,907
at 7% Tax-exempt, 30-yr term	
Total System O & M Costs	\$ 96,800
Total Annual System Needs at 1.3 x Debt Coverage	\$ 968,119
ANNUAL SOURCES OF FUNDS	
Annual Farebox Baseline VHSR Revenues	\$ 257,996
Annual Farebox Aggressive VHSR Revenues	\$ 330,562
Freight Revenues*	\$ 231,000
AMOUNT OF FUNDING SHORTFALL	
VHSR Baseline	\$ 479,122
VHSR Aggressive	\$ 406,556

*Freight revenues are based on the following assumptions:
the HSGT system is mature; it extends throughout the Northeast and west to Chicago; and
shipping and sorting facilities are in place at the various destinations.

Table 7-7-C. NYS VHSR Private Financing Scenario.

Annual Debt Payment if System Would be Financed by Private, Taxable Revenue Bonds (11% Interest, 30 yr term)	\$ 924,786
Total System Operations & Maintenance Costs	\$ 96,800
Total Annual System Needs at 1.3 x Debt Coverage	\$1,328,062
Annual VHSR Baseline Farebox Revenues	\$ 257,996
Annual VHSR Aggressive Farebox Revenues	\$ 330,562
Annual Freight Revenues*	\$ 231,000
Amount of Funding Shortfall - Baseline VHSR	\$ 839,066
Amount of Funding Shortfall - Aggressive VHSR	\$ 766,500

*Freight revenues are based on the following assumptions:
the HSGT system is mature; it extends throughout the Northeast and west to Chicago; and
shipping and sorting facilities are in place at the various destinations.

Table 7-8-A. NYS Maglev Revenue Bond Financing Pro Forma Assumptions (1993 dollars).

USES OF FUNDS	THOUSANDS OF DOLLARS
Design & Engineering Management	\$2,155,140
Right-of-Way Acquisition & Negotiation	\$ 400,000
Rolling Stock	\$ 259,200
Special Equipment	\$ 18,000
Construction Capital Costs	\$11,695,797
SUBTOTAL	\$14,528,137
20% Contingency	\$2,272,599
SUBTOTAL including 20% contingency	\$17,002,736
Capitalized Construction Interest	\$1,422,398
Total System Capital Costs	\$18,425,134
Annual O&M Costs	
Labor Costs	\$ 39,400
Materials Costs	\$ 61,000
Total Annual O&M Expenses	\$ 100,400
Annual Sources of Funds	
Freight Revenues*	\$ 231,000
Maglev Farebox Revenues (using new 2010 revenues and aggressive scenario)	\$ 533,459

*Freight revenues are based on the following assumptions:
the HSGT system is mature; it extends throughout the Northeast and west to Chicago; and
shipping and sorting facilities are in place at the various destinations.

Table 7-8-B. NYS Maglev Bonding Needs and Coverage Ability of Farebox Revenues.

Annual Uses of Funds	Thousands of Dollars
Total System Capital Costs of Debt at 7% tax exempt, 30 yr term	\$1,484,815
Total System O&M Costs	\$ 100,400
Total Annual System Needs at 1.3 x Debt Coverage	\$2,060,780
Annual Sources of Funds	
Fare Box Revenues (aggressive maglev)	\$ 533,429
Freight Revenues*	\$ 231,000
Amount of Funding Shortfall	\$1,296,321

*Freight revenue estimates are based on a mature, regional HSGT system and shipping and sorting facilities are in place at destination cities.

Table 7-8-C. NYS Maglev Private Financing Scenario Economic and Financial Analyses.

Annual Debt Payment if System Would be Financed by Private Taxable Revenue Bonds at 11% interest, 30 yr term	\$2,119,344
Total System O&M Costs	\$ 100,400
Total Annual System Needs at 1.3 x Debt Coverage	\$2,885,667
Annual Farebox Revenues	\$ 533,459
Annual Freight Revenues*	\$ 231,000
Amount of Funding Shortfall	\$2,121,208

*Freight estimates are based on a mature, regional HSGT network with shipping and sorting facilities in place at destination cities.

FINANCING SUMMARY

With fares set at rates to achieve maximum revenue, HSR and Maglev systems will raise enough revenues to cover annual O&M costs. However, the annual revenues raised from fares for a system limited to New York State will not cover the capital costs.

Given the significant financial investment associated with both HSR and Maglev, New York State must seek significant support from the Federal government and the private sector. This partnership is crucial to support the extensive research and development associated with prototyping new technology, guarantee financial success, and manage construction and operation of the world's first Maglev system or implement a true HSR project in the United States.

A strong Federal partnership is usual for other forms of public transportation where capital assistance is among the most common methods for government to facilitate the development of needed services. Airports, for example, are usually developed by the public sector for use by private air carriers. Public transit systems receive significant public funding for their capital needs as well as on-going operating costs. AMTRAK relies on public support for virtually all its capital need and a portion of ongoing operations. Northeast Corridor improvements between Boston and Washington were and continue to be paid for by 100 percent Federal funding. Finally, the National Highway System is usually improved with public funding, with the Federal government paying 80 percent for most regional improvements on the Interstate Highway system.

At the Federal level, there is growing momentum to support development of HSGT transportation network. Thanks to Senator Moynihan of New York, the Intermodal Surface Transportation Efficiency Act of 1991 reflects the growing interest in HSGT by authorizing \$800 million for research and development of Maglev and HSR. In 1993, The Clinton administration proposed a \$1.3 billion National High Speed Railroad Development Program.

In November 1993 New York State's governor Mario M. Cuomo and Lt. Governor Stan Lundine announced a Proposal for High Speed Ground Transportation in the State of New York. This proposal identified a 75 percent Federal contribution to New York's HSR improvement projects and Maglev development initiative. This contribution is equivalent to Federal support of other modes of transportation at a level already authorized for the Federal Maglev demonstration project.

New York State is in an excellent position to take immediate advantage of fund made available through any Federal High Speed Rail program. In fact, if the criterion in the Proposed High Speed Rail Development Act remains 125 miles per hour or higher, New York's Empire Corridor may be the only corridor in the country with a reasonable chance of meeting the criterion in the near term.

Both incremental improvements to New York's existing rail corridor and Maglev are expected to fully cover ongoing O&M costs and, in the case of Maglev, system revenues may also help recover some portion of the capital costs, particularly if regional extensions are implemented. The timing and firm commitment of Federal cost-share dollars to these initiatives is necessary for the development of a complete financial analysis.

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