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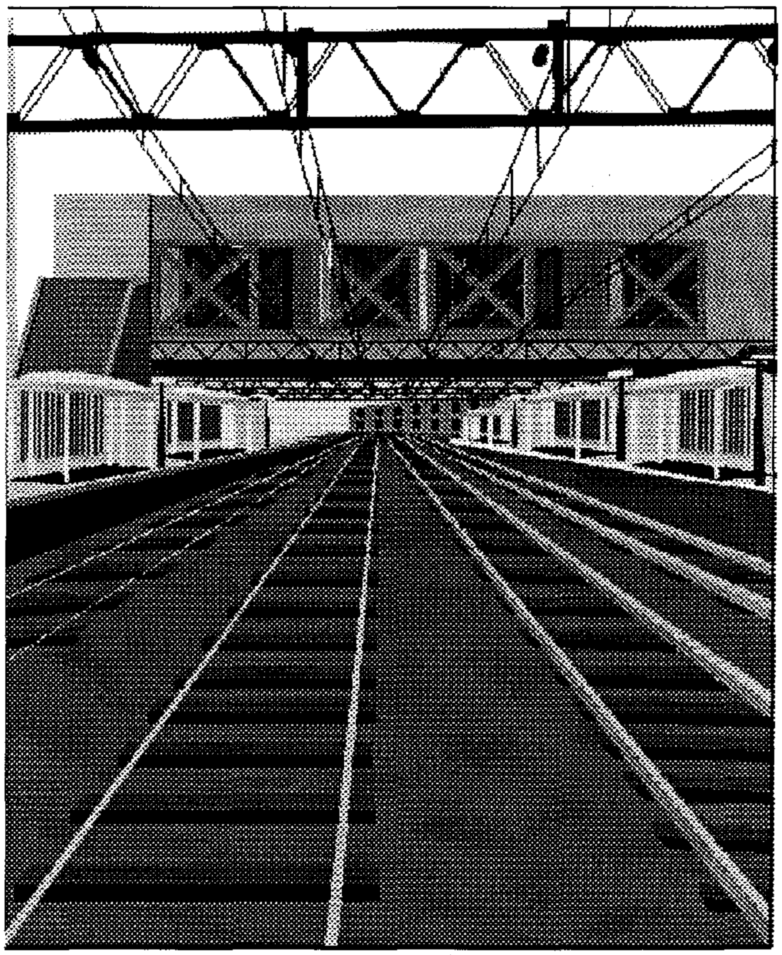
May 1993



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13. ABSTRACT (Maximum 200 words)

This study documents potential system improvements to benefit commuter and intercity rail passenger service in the Boston-New York corridor. It addresses the nature, cost and benefits of major investments in the infrastructure. The results of previous studies, analyses and estimates by the involved public agencies, operating railroads and others, are incorporated by the study team.

The study identifies major infrastructure rehabilitation and improvement projects and organizes them into a logical hierarchy of five overall programs. The major projects are identified and characterized. The first program consists of a basic set of five projects required to maintain the existing system capability. Four improvement programs are further defined by incorporating higher levels of system improvement projects.

Potential savings in intercity trip times from each of the five programs are calculated for various types of operating equipment. Commuter trip time impacts are also estimated. Ridership gains from reduced trip times are projected from demand models.

The projected improvement programs would result in significantly reduced trip times for the New York-Boston/Boston-New York segment, maybe as low as 2-1/2 hours, depending on the level of investment and the rolling stock used. Substantial speed and reliability benefits for commuter rail service are discussed.

14. SUBJECT TERMS
Northeast Corridor Rail System, commuter rail transportation, intercity rail transportation, Amtrak, Metro-North Commuter Railroad, Massachusetts Bay Transportation Authority

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PREFACE

The study described in this document was carried out under the overall direction of a Departmental Task Force consisting of the FTA and FRA Administrators and the Counselor to the Secretary of Transportation. The program manager was S. Barsony of the Federal Transit Administration. The Volpe Center effort was directed by R. Madigan; J. Hopkins was responsible for technical coordination of the efforts of the multi-disciplinary study team and integration of its efforts. Other key Volpe Center staff members on the team included P. Mattson (civil engineering), M. Safford (institutional and financial aspects), and D. Pickrell (ridership and benefits). Extensive technical support was provided by Parsons Brinckerhoff Quade & Douglas, Inc, under the direction of J. Harrison; K. Ullman conducted the curve analysis, a critical element of the study. Estimates of future ridership were developed by Charles River Associates. The study benefitted greatly from the active cooperation of many organizations and individuals; appreciation is expressed particularly to R. Rathbun (Connecticut Department of Transportation), E. Courtemanch (Amtrak), and H. Permut (Metro-North Commuter Railroad).

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2 = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2 = 0.09 square meter (m$_2$)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (1)
1 pint (pt) = 0.47 liter (1)
1 quart (qt) = 0.96 liter (1)
1 gallon (gal) = 3.8 liters (1)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] ^{o}F = y ^{o}C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yeards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliters (ml) = 0.03 fluid ounce (fl oz)
1 liter (1) = 2.1 pints (pt)
1 liter (1) = 1.06 quarts (qt)
1 liter (1) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] ^{o}C = x ^{o}F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES: 0 1 2 3 4 5 6 7 8 9 10

CENTIMETERS: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 25.40

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

^{o}F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
^{o}C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

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LIST OF ABBREVIATIONS

CDOT	Connecticut Department of Transportation
CR	Conrail
FRA	Federal Railroad Administration
LIRR	Long Island Rail Road
MBTA	Massachusetts Bay Transportation Authority
MNCR	Metro-North Commuter Railroad
MTA	Metropolitan Transportation Authority
NEC	Northeast Corridor
NECIP	Northeast Corridor Improvement Program
NJT	New Jersey Transit
P&W	Providence and Worcester Railroad
RIDOT	Rhode Island Department of Transportation
ROW	Right-of-Way
TPC	Train Performance Calculator
UMTA	Urban Mass Transportation Administration (Now the Federal Transit Administration)
VNTSC	Volpe National Transportation Systems Center

EXECUTIVE SUMMARY

INTRODUCTION

This study documents potential system improvements to benefit commuter and intercity rail passenger service in the Boston-New York corridor. The study was conducted by the Volpe National Transportation Systems Center (VNTSC) for the Department of Transportation under the direction of a Task Force established by the Secretary of Transportation.

Background

The Northeast Corridor (NEC) serves a populous and heavily travelled region for which railroad passenger transportation is particularly suitable. Extensive Commuter rail passenger service on the Corridor is essential to the metropolitan areas served. Seven transportation authorities and railroads use more than one-half of the 231 miles of NEC between Boston and New York to provide commuter rail services for over 100,000 riders every weekday. This represents well over 90% of NEC riders and two-thirds of total passenger-miles on the Corridor.

The Corridor has long had a major role in intercity passenger travel, currently carrying 2.3 million riders annually on the route between Boston and New York. Growth of airport and highway congestion has contributed to increased interest in improving passenger rail performance on the northern half of the NEC. The $2.5 billion Northeast Corridor Improvement Program (NECIP) of the 1970s and 1980s resulted in a reliable trip time under 3 hours for rail travel between New York and Washington, which in turn contributed to a high level of ridership. The shortest Boston-New York rail travel time is currently just under 4 hours, which has not proven to be competitive with air transport for many time-sensitive travellers on this route.

Much of the Corridor's fixed plant, such as bridges and catenary, is 80 years old or older. As a result, major rehabilitation and replacement will be required simply to assure safety and bring the railroad to a state of good repair. The responsible agencies are currently planning and conducting programs to meet those needs, but funding constraints are such that the necessary rehabilitation will take many years, and new needs continue to accumulate. Similarly, investments are being made to shorten trip times, but there is no assurance that funds will be available after 1991.

The multiple services which the Corridor supports are reflected in a complex institutional structure. Table 1 shows the division of responsibilities among various organizations for the Boston-New York portion of the NEC.

TABLE 1. INSTITUTIONAL ROLES AND RESPONSIBILITIES FOR THE NORTHEAST CORRIDOR BETWEEN BOSTON AND NEW YORK CITY

From	To	Distance (miles)	Owner	Maintenance	Dispatching	Commuter Service	Commuter Authority	Freight Service
Penn Station	Harold Interlocking	4	Amtrak	Amtrak	Amtrak	LIRR	MTA	--
Harold Interlocking		--	LIRR	LIRR	LIRR	LIRR	MTA	--
Harold Interlocking	Shell Interlocking	15	Amtrak	Amtrak	Amtrak	--	--	Conrail
Shell Interlocking	NY-CT State Line	10	MTA	MNCR	MNCR	MNCR	MTA	Conrail
NY-CT State Line	New Haven	46	CDOT	MNCR	MNCR	MNCR	CDOT	Conrail
New Haven	Old Saybrook	33	Amtrak	Amtrak	Amtrak	Amtrak	CDOT	Conrail
Old Saybrook	RI-MA State Line	86	Amtrak*	Amtrak	Amtrak	--	--	P&W
RI-MA State Line	Boston	38	MBTA	Amtrak	Amtrak	Amtrak	MBTA	Conrail

* RI DOT owns approximately 1/4-mile of track through and adjacent to Providence Station.

Purpose

In response to the Administration's goals expressed in the National Transportation Policy, VNTSC performed this study to identify and characterize costs and benefits of improvements which could be achieved in commuter and intercity rail service on the Boston-New York portion of the Corridor. The study focused in particular on the following questions:

- What improvements are needed to assure safety and continued reliable operations on the Corridor?
- What could be done to the NEC fixed plant infrastructure to achieve substantially faster and more reliable commuter and intercity rail service?
- What degree of rail service improvement is attainable for various levels of capital investment, and what is a logical sequence or order for implementing these improvements?
- What benefits would various levels of improvement have for intercity ridership on rail, air and highway modes?
- What benefits would improvements have for commuters?

The study clarifies the nature, cost and benefits of major investments in the Boston-New York rail infrastructure. As such, it can provide a basis for developing the consensus among owners, operators and all levels of government necessary for policy formulation and decision making. It brings together, in a consistent and comprehensive manner, the results of studies, analyses and estimates by the involved public agencies, operating railroads and others, as well as independent assessments by the study team.

The study is not a program plan for the improvement of the corridor, and therefore does not include new designs, nor does it refine existing designs initiated by the participating public agencies and railroads.

Methodology

General Approach: The study identifies major infrastructure rehabilitation and improvement projects and organizes them into a logical hierarchy of overall programs. As appropriate, it integrates the results of prior studies of infrastructure needs using 1991 cost estimates. Potential savings in intercity trip times from each of the five programs are calculated for various types of equipment using the proven Train Performance Calculator (TPC) computer program. Commuter trip time impacts are also estimated from the TPC results for the express portions the run, assuming no gains for nonexpress segments. However, rolling stock investments and normal operating and maintenance costs are not analyzed. Ridership gains are projected from demand models based on the calculated schedule times for the different improvements. The study also estimates the benefits in time savings for both intercity passengers and commuters.

The major projects comprising alternative improvement programs are identified and characterized, but no single blueprint is presented for upgrading the Northeast Corridor. That must await consensus as to goals, funding, and process among the many involved private and public bodies. Detailed schedules, cost estimates and spending plans for any accepted program could then be developed.

Assumptions: Key assumptions of the study were as follows:

- **Time Frame:** Project implementation and funding allocation is assumed to occur between 1991 and 2000. Ridership projections are for 2010.

- **Route/Right-of-Way:** Improvements considered are primarily those that can be made within the existing right-of-way, with the exception of a new inland route segment recently studied by Amtrak.

- **Rolling Stock:** The performance projections assume equipment that is now available, or sufficiently developed and tested so that it would be available for revenue service. Costs would depend on the level of service and other operational variables.

- **Speed on Curves:** The study assumes that with modern rolling stock and rehabilitated and reconfigured track, higher curve speed limits will be acceptable in terms of safety and passenger comfort.

IMPROVEMENT PROGRAMS

A hierarchy of five alternative programs was defined. All programs include a basic set of five projects needed to maintain safety and rehabilitate existing infrastructure. The program alternatives are tabulated at the end of the Executive Summary. The first program (System Rehabilitation) consists only of these five projects. The other four programs include concurrent implementation of system improvement projects, offering shorter trip times while requiring higher levels of funding. Most of the projects in the System Rehabilitation program are already in progress, but are not fully funded.

Program 1: System Rehabilitation

The System Rehabilitation Program consists of five projects necessary for improved safety and for replacement of major system elements which have exceeded their normal service life. This program represents a continuation of an ongoing process. Over half of the projects are at least partially funded. More than $100 million has been obligated to date. The various responsible agencies are developing long-term plans covering most of the projects which comprise Program 1, although funding constraints limit the pace of implementation.

The system rehabilitation projects would be needed for continued safe and efficient operation, in essentially the same form, in the absence of any speed and reliability improvement efforts. Thus, they are necessary elements of all system improvement programs, but need not be completed prior to initiation of system improvement projects. Program 1 includes two safety projects: replacement of Peck Bridge, and fire safety ventilation and other improvements to Penn Station and the East River Tunnels. It provides a necessary framework for substantial improvements in speed.

Program 1 yields improved reliability and slightly reduced trip time for commuter and intercity services. Boston-New York schedules would be shortened by several minutes, primarily by greater speeds at some movable bridges and operation use of two diesel locomotives rather than one between Boston and New York. Maximum operating speed is 110 MPH. The currently unfunded portion of the cost of this program is estimated to be $1.1 billion (in 1991 dollars). Approximately one-third of this sum has been programmed by the various operating authorities, based on expected funds availability during the next decade.

Program 2: Basic System Improvements

The Basic System Improvement Program includes the five projects in the System Rehabilitation Program as well as ten projects to improve service reliability and speed. More than 30 minutes can be cut from intercity running time by trackwork and signaling, in conjunction with higher allowed speeds on curves, that increases running speeds to a maximum of 130 MPH. Modernization of the New Haven terminal area will eliminate an extended region of very slow speeds, cutting an additional 5 minutes from the trip. Other projects are necessary for capacity enhancement, grade crossing improvements, assured service reliability and avoidance of serious delays at locations where intercity and commuter lines merge or cross.

The rehabilitation projects need not be completed, nor some even initiated, prior to beginning speed and reliability improvements. Most of the system improvement projects in Program 2 are already at least in the preliminary design phase, and expenditures or commitments of $80 million have already been made. The highest Boston-New York average speed attainable with this program is 75 MPH. The program adds a cost averaging $50 million/year over 10 years to the system rehabilitation program, but yields a trip time approaching 3 hours for Boston to New York. Significant time savings are also achieved for commuters in the New York area.

Program 3: Basic System Improvements and Electrification

Program 3 adds electrification of the route from Boston to New Haven to the projects of Program 2. Electrification, for which initial design funds have been provided, eliminates the engine change in New Haven, a saving of almost 9 minutes, and allows use of electric locomotives for the Boston-New Haven segment. The electric units, with higher acceleration, operating at up to 130 MPH, will further reduce trip time by almost 6 minutes. Electrification also facilitates run-through operation between Boston and Washington, necessary for improving Pennsylvania Station and East River Tunnel capacity and providing high-speed service to and from points south of New York. Average speed for express service, depending on rolling stock, is slightly above 80 MPH, with a projected best trip time slightly less than 3 hours. Significant time savings are achieved for commuters in the New York area, and potentially in the Boston area.

Electrification includes associated signal upgrade and bridge clearance projects. Program 3 requires an additional expenditure of $470 million. In 1991 $25 million was appropriated by Congress for electrification design; Amtrak has recently solicited and received bids for the project.

Program 4: All System Improvements and Electrification

This program includes all projects in Program 3 and adds a program of realignments to permit higher speed on curves, primarily between Providence and New Haven; maximum speed is 130 MPH. The curve realignments are estimated at $715 million, and would yield an average speed of about 90 MPH. These improvements provide an additional reduction in trip time of about 11 minutes; the Boston-New York trip could be completed in less than 2¾ hours.

If the Boston-New Haven line were electrified prior to implementing realignments, the cost of subsequent curve straightening would be substantially increased. Thus, a choice between Programs 3 and 4 must be made prior to implementation; Program 4 would not be practical as a later upgrade from Program 3. Selection of Program

3 would be likely to preclude the possibility of obtaining the trip time reductions associated with straightening of these curves.

Program 5: Shore Line Bypass

Program 5 adds to Program 4 a new routing to avoid the most curve-intensive portion of the route. The "Shore Line Bypass," recently examined by Amtrak, is a 50-mile long 150-MPH right-of-way to replace the most curved section of the route along the Connecticut and Rhode Island shore east of New Haven. This route could yield an average speed of approximately 95 MPH. The $850 million cost increment from Program 4 takes into account deductions for costs in Programs 2 through 4--such as some of the curve realignments--which would not be needed if a bypass were constructed. However, those deductions would not apply if Program 3 or 4 was implemented and a later decision was made to construct a bypass. The Boston-New York trip time could be 2½ hours or better, depending on the operating equipment.

The four system improvement programs yield projected Boston-New York trip times of from 3 hours down to less than 2½ hours, depending on the level of investment and the rolling stock used, along with substantial speed and reliability benefits for commuter rail service.

SPECIFIC IMPROVEMENT PROJECTS

Table 2 shows the system rehabilitation and improvement projects identified and the hierarchy of programs developed from them. Cost estimates for each of the programs include fixed-plant capital costs only; rolling stock is not included. All costs are in 1991 dollars, and do not include funds already appropriated for specific projects. Independent engineering cost estimates, based on prior studies and other information from NEC owner and operator agencies, were made for individual projects for which no recent detailed analyses were available. In most cases, these estimates included escalation by 30% to include contingencies and an additional 23% for combined design, management and administration functions. Program elements, costs, and proposed sequencing for all programs are presented in Figures 1 through 5 at the end of this Executive Summary.

Actual future-year project funding would be higher than shown, due to the effects of inflation. For example, the replacement of Peck Bridge is shown in the table as having an unfunded cost of $86 million in 1991 dollars. However, during 8 years of design and construction the cost will be $129 million in current-year (escalated) dollars, of which $23 million has already been appropriated, leaving $106 million still required. Table 2 shows only unfunded cost. It does not, for example, include the $25 million already provided in the 1991 FRA appropriation for electrification or the $25 million for Shell Interlocking. The breakdown between funded and unfunded costs is shown in Figures 1-5.

PERFORMANCE AND COST OF THE PROGRAMS

Table 3 shows, for each improvement program, the projected minimum running time between Boston and New York City for express (Metroliner-type) service. Run times are based on computer simulation plus a 5% schedule allowance for normal variations and delays.

Travel time estimates assume the four intermediate stops of Amtrak's present New England Express schedule (Back Bay, Route 128, Providence, New Haven). Six-coach trains were selected for train performance calculations, as is consistent with proposed future express service. **The trip times shown in the table are the best which might be achieved. Reliable attainment of those values would require full validity of all assumption and railroad operations which meet the highest standards of precision and reliability in all respects.** Practical scheduled running times could be several minutes greater than the values shown in Table 3. An additional stop in Stamford, which is likely for many trains, would add approximately 3 minutes.

TABLE 2. COST OF PROJECTS COMPRISING NEC ALTERNATIVE IMPROVEMENT PROGRAMS IN MILLIONS OF 1991 DOLLARS

PROGRAM:	1. SYSTEM REHABILITATION	2. BASIC SYSTEM IMPROVEMENTS	3. BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION	4. ALL SYSTEM IMPROVEMENTS AND ELECTRIFICATION	5. SHORE LINE BYPASS
REHABILITATION PROJECTS					
Penn Station/Tunnel	$ 366 M	$ 366 M	$ 366 M	$ 366 M	$ 366 M
Catenary Replacement	350	350	350	350	350
Peck Bridge Replacement	86	86	86	86	86
Movable Bridges	64	64	64	64	10
Fixed Bridges	213	213	213	213	213
SYSTEM IMPROVEMENT PROJECTS					
Harold Interlocking		65	65	65	65
Shell Interlocking		30	30	30	30
Stamford Island Platforms		30	30	30	30
New Haven Terminal Area		55	55	55	55
New Hvn-Norwalk 4th Trk		20	20	20	20
Canton Viaduct		9	9	9	9
Track Improvements		214	214	214	214
Signal System Upgrades		14	39	44	44
Grade Crossings		10	10	10	0
Station Improvements		32	32	32	32
Electrification*			445	445	445
Curve Realignments				715	450
Bypass Alignment					1180
TOTAL PROGRAM COST	$1.1 B	$1.6 B	$2.0 B	$2.7 B	$3.6 B

* Electrification figure includes cost of achieving adequate bridge clearances.

NOTE: Some projects have already received initial funding by State or Federal agencies. The cost shown in this table is that portion of the total cost in excess of current and past appropriations, expressed in 1991 dollars. Values shown here generally will not agree with escalated budget figures for future years.

As shown in Table 3, four motive power alternatives are considered in establishing the range of trip time which fixed plant improvements could yield. Assessment of the suitability of specific rolling stock to actual Corridor operations is not within the scope of this study. The current-technology diesel and electric units on which trip time projections are based are assumed usable with either conventional coaches or with cars having a tilting suspension, which would permit somewhat higher speed on curves. The high-speed electric equipment represents advanced technology now in use in Europe.

The "turbo" power unit used for trip time estimates is patterned after gas turbine equipment now in service on Amtrak's Empire Line, for which two power cars together have a net of 2280 HP. A version making use of twin turbines of newer design on each power car, with a total power of 5800 HP, has been proposed. If this equipment were successfully developed and tested, turbo trip time would be improved. However, even an advanced turbine train would be likely to have weaknesses in NEC service. It would not be suited to Boston-Washington run-through service, and would have to resolve concerns relating to third-rail operation in tunnels and operational reliability and flexibility.

TABLE 3. ESTIMATED RUNNING TIME BETWEEN BOSTON-NEW YORK FOR EXPRESS (METROLINER TYPE) SERVICE. (HOURS:MINUTES). Cost shown is that portion of total cost for which no funds are currently appropriated, in 1991 dollars

PROGRAM: / ROLLING STOCK:	1. SYSTEM REHABILITATION	2. BASIC SYSTEM IMPROVEMENTS	3. BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION	4. ALL SYSTEM IMPROVEMENTS AND ELECT.	5. SHORE LINE BYPASS
CURRENT DIESEL/ ELECTRIC (NEC)[1]	3:47	3:07	SYSTEM FULLY ELECTRIFIED DIESEL-ELECTRIC AND GAS TURBINE NOT APPLICABLE		
CURRENT DIESEL/ ELECTRIC WITH TILT	3:46	3:02			
CURRENT TURBO (Empire Line)[2]	3:48	3:21			
ELECTRIC[3]	SYSTEM NOT FULLY ELECTRIFIED ELECTRIC PROPULSION NOT USABLE OVER FULL ROUTE		2:52	2:41	2:29
ELECTRIC/TILT			2:47	2:37	2:28
HIGH-SPEED ELECTRIC[4]			2:46	2:35	2:22
HIGH-SPEED ELECTRIC/TILT			2:41	2:33	2:21
TOTAL PROGRAM COST ($B)	$ 1.1 B	$ 1.6 B	$ 2.0 B	$ 2.7 B	$ 3.6 B[5]

Footnotes: 1. 2 F40P diesel-electric locomotives Boston-New Haven; AEM7 electric New Haven-New York; 10 min. change.
2. Gas Turbine-powered equipment comparable to that used for current Amtrak Empire Line service.
3. 1 AEM7 locomotive, modified for 150 MPH for Program 5; use of 2 AEM7's improves time by 5 minutes.
4. Lightweight, high-powered equipment comparable to TGV or ABB trainsets.
5. Estimate includes adjustment for movable bridge and curve projects made unnecessary by the bypass.

All trains consist of six coaches and make 1 ¼-min. stops at Back Bay, Route 128, Providence and New Haven. Computed times are increased by 5% to allow for operational variability and uncontrollable delays. All programs assume acceptability of higher speeds on curves than are now allowed (6" superelevation, 6" unbalance for conventional coaches and 8" for tilt suspensions) - See Section 4.

Rolling stock cost and operating and maintenance expenses were not analyzed in detail. However, a rough estimate of rolling stock capital cost is possible. Trainsets, consisting of two power units and six coaches, are expected to cost about $20 million each. As many as 15 to 20 such trainsets might be needed to augment the existing fleet, depending on the program selected and the resulting ridership levels.

BENEFITS

Table 4 summarizes estimated benefits expected to result from improved commuter and intercity running times for each of the four system improvement programs. Projected ridership is shown along with three benefit measures: number of riders projected to be diverted from air and highway modes; cumulative hours of time savings by commuters and intercity riders; and potential annual Amtrak net operating income arising from each program. All benefits are estimated for the year 2010. The projected ridership figures can be compared to the 1989 total of 2.3 million passengers, the 3.4 million projected for 2010 in the absence of any improvements or operational changes, and approximately 3.9 million for system rehabilitation only, accompanied by hourly departures of both conventional and *New England Express*-type service.

Table 4 shows mid-range values of ridership for the various rolling stock alternatives. An important factor in generating this ridership is the assumption of increased intercity departure frequency. Improved nonexpress service (approximately 30 minutes slower than express, but with more intermediate station stops and a lower fare) is assumed to coexist with higher speed Metroliner-type service; it contributes a large portion of the time savings for intercity riders. Table 4 includes trips between points within the corridor and locations south of New York.

The improvement program to be implemented--which defines the overall rail system of which each project is a part--must be defined before detailed design of that project and sequencing of construction can be completed. Some projects have direct logistic connections with one another, as with trackwork, signaling and electrification. Others are linked operationally, such as Stamford Platforms and improvements at Shell Interlocking, or are connected through the need to minimize disruption of traffic during construction. Improving the Corridor one project at a time, without clear definition of the planned end state, would be very inefficient and yield poor results.

TABLE 4. SUMMARY OF RIDERSHIP, DIVERSION FROM OTHER MODES, TIME SAVINGS TO RIDERS, AND CHANGE IN AMTRAK NET REVENUES

PROGRAM:	2. BASIC SYSTEM IMPROVEMENTS	3. BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION	4. ALL SYSTEM IMPROVEMENTS AND ELECT.	5. SHORE LINE BYPASS
ANNUAL INTERCITY RIDERSHIP (MILLIONS)	4.7	5.0	5.3	5.6
NEW RIDERS DIVERTED FROM: AIR: (MILLIONS)	1.6	1.9	2.1	2.4
HIGHWAY:	.5	.5	.6	.6
ANNUAL TIME SAVINGS (MILLIONS OF HOURS) COMMUTERS:	5.0	5.8	5.8	5.8
INTERCITY:	2.6	4.1	4.7	5.1
POTENTIAL CHANGE IN AMTRAK ANNUAL NET OPERATING INCOME (MILLIONS OF DOLLARS)	\$36 - 55 M	\$97 - 116 M	\$123 - 136 M	\$146 - 168 M

CONCLUSIONS

1. Program 1, System Rehabilitation, costing about \$1.1 billion, is needed to assure safety and maintain the present level of intercity and commuter rail service between Boston and New York. Some of this work has been initiated by the responsible agencies, but funds available or planned for these projects over the next decade represent about one-third of the amount needed for full implementation. These projects will contribute to Corridor safety and reliability well into the next century.

2. Trip time can be improved substantially using existing technology and with little or no excursion beyond the existing NEC right-of-way. The time for a trip from Boston to New York could be reduced to approximately 2½ to 3 hours, depending on the size of the investment made and the rolling stock selected.

3. Much of the NEC investment would be in segments heavily used by commuter rail passengers. These commuters would, in many cases, experience long-term service improvements comparable to those for intercity riders, as well as increased system capacity. Estimated cumulative time savings for commuters in the year 2010 are 5.8 million hours annually. On the other hand, commuter railroads will bear much of the burden of service interruptions during construction, and will be subject to new constraints, costs and requirements concerning track maintenance, compatibility of rolling stock and dispatching.

4. Large reductions in trip time can be expected to increase Amtrak ridership between Boston and New York. Compared to a baseline of 3.4 million passengers per year estimated for 2010 with no improvements, ridership of about 5 million is projected for a 3-hour trip time and 5.5 million for a 2½-hour trip time. Time savings for current intercity passengers would range from approximately 3 to 5 million hours annually. Approximately 80% of the new passengers would be diverted from air, with 20% from private auto.

5. The economic value of reduced travel time and increased ridership resulting from improved rail service is potentially large. Time savings to Amtrak riders, commuter rail travelers and airport and highway users are estimated to range from $100 million to $108 million annually for a trip time near 3 hours to as much as $172 million to $227 million each year for less-than-2½-hour service under Program 5. However, these estimates are not based on a benefit-cost analysis of the programs, and these trip time savings would require additional capital investment in rolling stock by both Amtrak and commuter-service operators.

6. Amtrak's increase in annual net revenue from trip time improvements is estimated to be in the range of $36 million to $168 million, depending on the travel time attained.

7. The cost of the improvements necessary for substantially reduced trip time, **in addition to the $1.1 billion for rehabilitation**, would range from an average of $50 million to $250 million annually for a ten-year program. Initial work is being undertaken on many of the needed projects, although only a small part of the needed funding has been identified and no coordinated overall program exists. The improvements could be implemented within a period of 8 to 10 years; service improvements could be apparent within 5 to 6 years. The necessary additional rolling stock (15 to 20 trainsets) could cost approximately $300 to $400 million.

8. Commuter and intercity schedules and service reliability will suffer during the implementation of any major improvements; the degradation of commuter service between New Haven and New York could be significant for a period of several years. A concerted effort will be required to design and sequence the improvements in a manner which minimizes disruption of service.

OTHER CONSIDERATIONS

Rolling Stock: The selection of a rolling stock alternative depends not only on the trip time it makes possible, but also on capital, operating and maintenance costs; reliability; suitability for run-through operation between Boston and Washington; and other characteristics and operational considerations.

The performance of advanced-technology high-speed foreign trainsets in the U.S. railroad environment remains to be evaluated. Demonstrations, trial use, and testing of a variety of motive power and railcar suspension technologies during the lengthy period of fixed-plant improvements would provide a good foundation for future long-term fleet acquisition decisions.

Electrification: Electrification between Boston and New Haven has important benefits and implications beyond travel time. Operationally, electrification harmonizes operations in the north and south ends of the Corridor, making it possible to use high-performance electric trainsets running between Boston and Washington, with few trains being turned around in New York. This provides needed capacity at Pennsylvania Station and in the tunnels serving it.

Corridor Capacity: This study did not explicitly examine Corridor capacity. Based on the improvements defined in Program 2 as a minimum, capacity appears to be adequate for anticipated commuter and intercity traffic through the 2010 time period. At Pennsylvania Station and the East River Tunnels operational improvements or changes may be required to avoid serious impacts, particularly on commuter operations. At other locations the system will be near or at its limit, and a concerted and integrated effort will be required to maximize Corridor capacity for all services.

Operating Standards: The projected higher speeds in all programs are based on the assumption that the FRA and Amtrak will approve higher speeds on curves, and define standards for rolling stock and inspection and maintenance procedures necessary for safe and comfortable operation at those speeds.

Institutional Coordination and Integration: Successful implementation of any major improvement program and practical attainment of the trip times estimated in this study will require a reinvigorated institutional and procedural framework. The direct responsibilities and objectives of the several owning and operating organizations differ significantly. The specific form of some projects, as well as the manner of implementation and cost allocation, can only be determined through compromise based on full consideration being given to all viewpoints. All parties--railroads, government agencies at all levels, and transportation authorities--will need to work in a highly coordinated and cooperative manner to define and realize a common vision of integrated Northeast Corridor rail services with equitable distribution of all capital and operational costs.

Financial Capacity for Implementation of Improvements: Currently, 1990 and 1991 funding of projects identified in this study totals $120 million for rehabilitation work (almost all from UMTA, MTA, NYDOT and CDOT), and $119 million for speed improvements and electrification (contained in the FY91 appropriation for Amtrak). However, financial constraints have tightened sharply in the last year, and current long-term plans of the responsible agencies show a shortfall over the next ten years of more than 50% in funding for rehabilitation projects. There is no currently authorized source of funds beyond FY91 for speed improvements.

Accessibility of Railroad Stations: The Americans with Disabilities Act of 1990 established specific accessibility standards for physically handicapped passengers for intercity and commuter rail stations and passenger cars. The Station Improvements project in this study includes an estimate for provision of high-level platforms and pedestrian overpasses at those Amtrak stations between Boston and New York not currently so-equipped. However, the special nature of the requirements of this act is considered beyond the general scope of the study, particularly insofar as commuter stations and rolling stock is considered.

TOPICS NOT ADDRESSED

During the course of this study, other topics were identified which would need to be addressed to support design, construction and scheduling decisions for any improvements. Topics warranting examination as logical next steps for any of the programs include:

(1) Testing and analysis to confirm the acceptability of higher speeds on curves, and to define standards necessary for safe and comfortable operation at those speeds.

(2) Analysis of long-term operating and maintenance costs of alternative improvement programs and rolling stock choices;

(3) System capacity and traffic conflict analysis, addressing both long-term outlook and impact on phasing of construction projects;

(4) Data collection and analysis to refine ridership projections and expected commuter and intercity benefits;

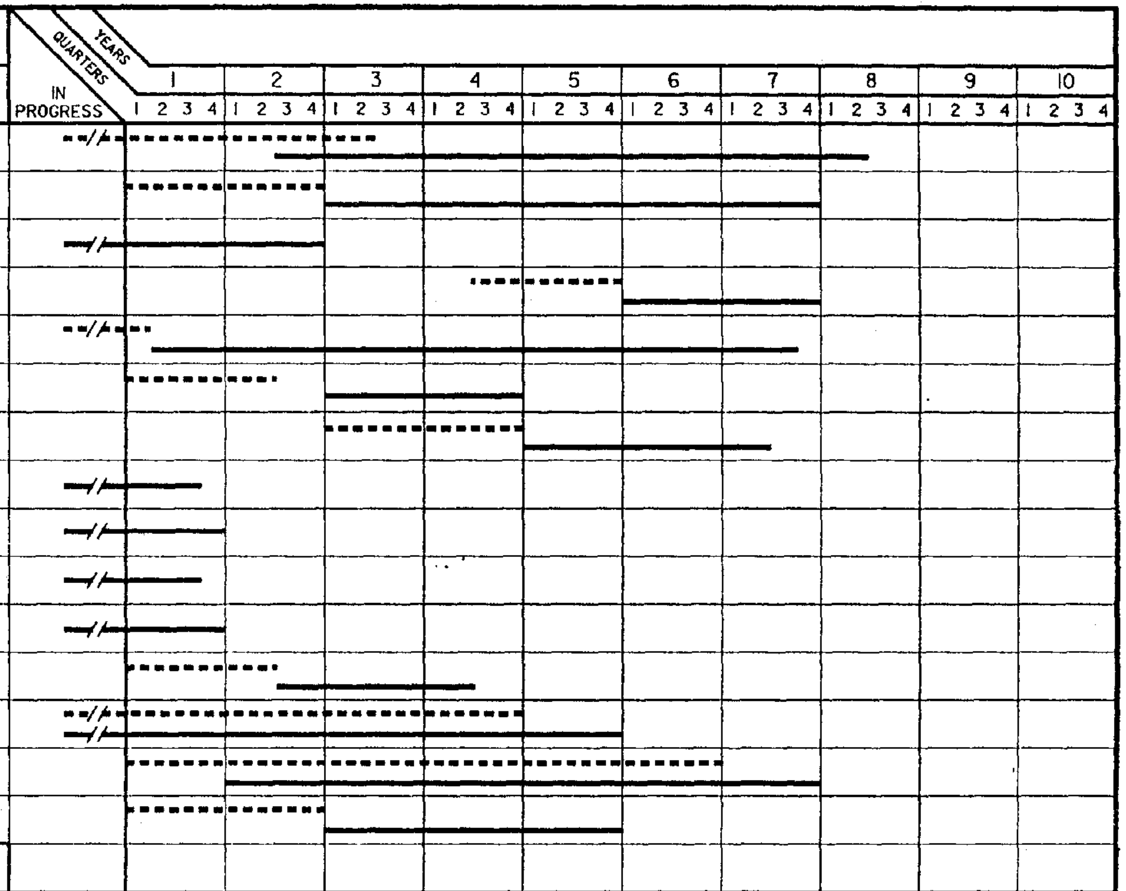
(5) Examination of the future role of rail freight transportation along the corridor, and the freight railroad impacts and benefits associated with Corridor improvements.

STUDY PARTICIPANTS

Many organizations own, operate, use, or are strongly affected by the Northeast Corridor, and their participation and active cooperation were critical to the study. In addition to extensive participation by knowledgeable individuals at UMTA and FRA, organizations that cooperated extensively by providing information and comment include:

- Amtrak
- Metro-North Commuter Railroad (MNCR)
- Long Island Rail Road (LIRR)
- Massachusetts Bay Transportation Authority (MBTA)
- Metropolitan Transportation Authority (MTA)
- Connecticut Department of Transportation (CDOT)
- Massachusetts Executive Office of Transportation and Construction
- Rhode Island Department of Transportation (RIDOT)
- New York Department of Transportation (NYDOT)
- Conrail
- Providence & Worcester Railroad (P&W)
- Northeast Corridor Commuter Rail Authorities Committee (NECCRAC)
- Coalition of Northeastern Governors (CONEG)

	PROJECT *	ESTIMATED COST (1991$ MILLIONS) UNFUNDED	FUNDED	TOTAL
1	N.Y. PENN STATION AND TUNNEL IMPROVEMENTS	366	9	375
2A	CATENARY REPLACEMENT (STATE LINE - NEW HAVEN)	347	0	347
2B	CATENARY REPLACEMENT (SHELL - STATE LINE)	0	24	24
2C	CATENARY STRUCTURE REHABILITATION (HELL GATE)	3	0	3
3	PECK BRIDGE REPLACEMENT	86	23	109
4A	MOVABLE BRIDGE - THAMES RIVER, MOVABLE SPAN	33	0	33
4B	MOVABLE BRIDGE - NIANTIC RIVER, ENTIRE BRIDGE REPLACEMENT	21	0	21
4C	MOVABLE BRIDGE - SAGA BRIDGE, REHABILITATION	0	9	9
4D	MOVABLE BRIDGE - COS COB BRIDGE, REHABILITATION	0	20	20
4E	MOVABLE BRIDGE - WALK BRIDGE, REHABILITATION	0	13	13
4F	MOVABLE BRIDGE - DEVON BRIDGE, REHABILITATION	0	17	17
4G	MOVABLE BRIDGE - PELHAM BAY BRIDGE, REHABILITATION	10	0	10
5A	FIXED BRIDGES - AMTRAK, NEW HAVEN-BOSTON CONVERSION TO BALLASTED DECK	43	5	48
5B	FIXED BRIDGES - METRO NORTH CONVERSION TO BALLASTED DECK	120	0	120
5C	FIXED BRIDGES - AMTRAK HELL GATE, VIADUCT REHABILITATION AND BRIDGE CONVERSIONS	50	0	50
	TOTALS	1,079	120	1,199



YEARLY EXPENDITURE † (1991$ MILLIONS)	IN PROGRESS	1	2	3	4	5	6	7	8	9	10
	120	55	105	200	194	183	162	151	29		

LEGEND

- - - - - ENVIRONMENTAL PROCESS, R.O.W. ACQUISITION AND DESIGN
——— CONSTRUCTION
* PROJECT DETAILS ARE CONTAINED IN APPENDIX A
† YEARLY EXPENDITURES ARE BASED SOLELY ON SEQUENCING CONSIDERATIONS AND NOT ON FUNDING AVAILABILITY

PROGRAM 1 - SYSTEM REHABILITATION

FIGURE 1. PROJECT COST ESTIMATES AND LOGICAL SEQUENCING FOR PROGRAM 1, SYSTEM REHABILITATION

	PROJECT *	ESTIMATED COST (1991 $ MILLIONS) UNFUNDED	FUNDED	TOTAL
1	N.Y. PENN STATION AND TUNNEL IMPROVEMENTS	366	9	375
2	CATENARY REPLACEMENT AND STR. REHABILITATION	350	24	374
3	PECK BRIDGE REPLACEMENT	86	23	109
4	MOVABLE BRIDGES	64	59	123
5	FIXED BRIDGES	213	5	218
6	HAROLD INTERLOCKING - (EASTBOUND FLYOVER)	65	0	65
7	SHELL INTERLOCKING - IMPROVEMENT	30	25	55
8	STAMFORD STATION - ISLAND PLATFORMS	30	0	30
9	NEW HAVEN STATION - YARD/APPROACH	55	5	60
10	NEW HAVEN - NORWALK, 4th TRACK	20	0	20
11	CANTON VIADUCT	9	1	10
12	TRACK IMPROVEMENTS (FULL SUPERELEVATION, FIT CURVES, ADDED TRACK, HIGH SPEED CROSSOVERS, CONCRETE TIE REPLACEMENT)	214	6	220
13	SIGNAL SYSTEM UPGRADES	14	56	70
14	GRADE CROSSING IMPROVEMENTS	10	0	10
15	STATIONS	32	1	33
	TOTALS	1,558	214	1,772

YEARS / QUARTERS	IN PROGRESS	1	2	3	4	5	6	7	8	9	10
YEARLY EXPENDITURE † (1991 $ MILLIONS)	214	118	183	237	244	248	227	216	78	6	6

LEGEND

- - - - - ENVIRONMENTAL PROCESS, R.O.W. ACQUISITION AND DESIGN

——— CONSTRUCTION

* PROJECT DETAILS ARE CONTAINED IN APPENDIX A

† YEARLY EXPENDITURES ARE BASED SOLELY ON SEQUENCING CONSIDERATIONS AND NOT ON FUNDING AVAILABILITY

PROGRAM 2 - BASIC SYSTEM IMPROVEMENTS

FIGURE 2. PROJECT COST ESTIMATES AND LOGICAL SEQUENCING FOR PROGRAM 2, BASIC SYSTEM IMPROVEMENTS

	PROJECT *	ESTIMATED COST (1991 $ MILLIONS) UNFUNDED	FUNDED	TOTAL
1	N.Y. PENN STATION AND TUNNEL IMPROVEMENTS	366	9	375
2	CATENARY REPLACEMENT AND STR. REHABILITATION	350	24	374
3	PECK BRIDGE REPLACEMENT	86	23	109
4	MOVABLE BRIDGES	64	59	123
5	FIXED BRIDGES	213	5	218
6	HAROLD INTERLOCKING (EASTBOUND FLYOVER)	65	0	65
7	SHELL INTERLOCKING IMPROVEMENT	30	25	55
8	STAMFORD STATION - ISLAND PLATFORMS	30	0	30
9	NEW HAVEN STATION - YARD/APPROACH	55	5	60
10	NEW HAVEN - NORWALK, 4th TRACK	20	0	20
11	CANTON VIADUCT	9	1	10
12	TRACK IMPROVEMENTS	214	6	220
13	SIGNAL SYSTEM UPGRADES	39	56	95
14	GRADE CROSSING IMPROVEMENTS	10	0	10
15	STATIONS	32	1	33
16A	NEW HAVEN - BOSTON ELECTRIFICATION	345	25	370
16B	VERTICAL CLEARANCE ATTAINMENT	100	0	100
	TOTALS	2,028	239	2,267

YEARLY EXPENDITURE † (1991 $ MILLIONS)	IN PROGRESS	1	2	3	4	5	6	7	8	9	10
	239	127	213	269	346	349	306	291	118	5	4

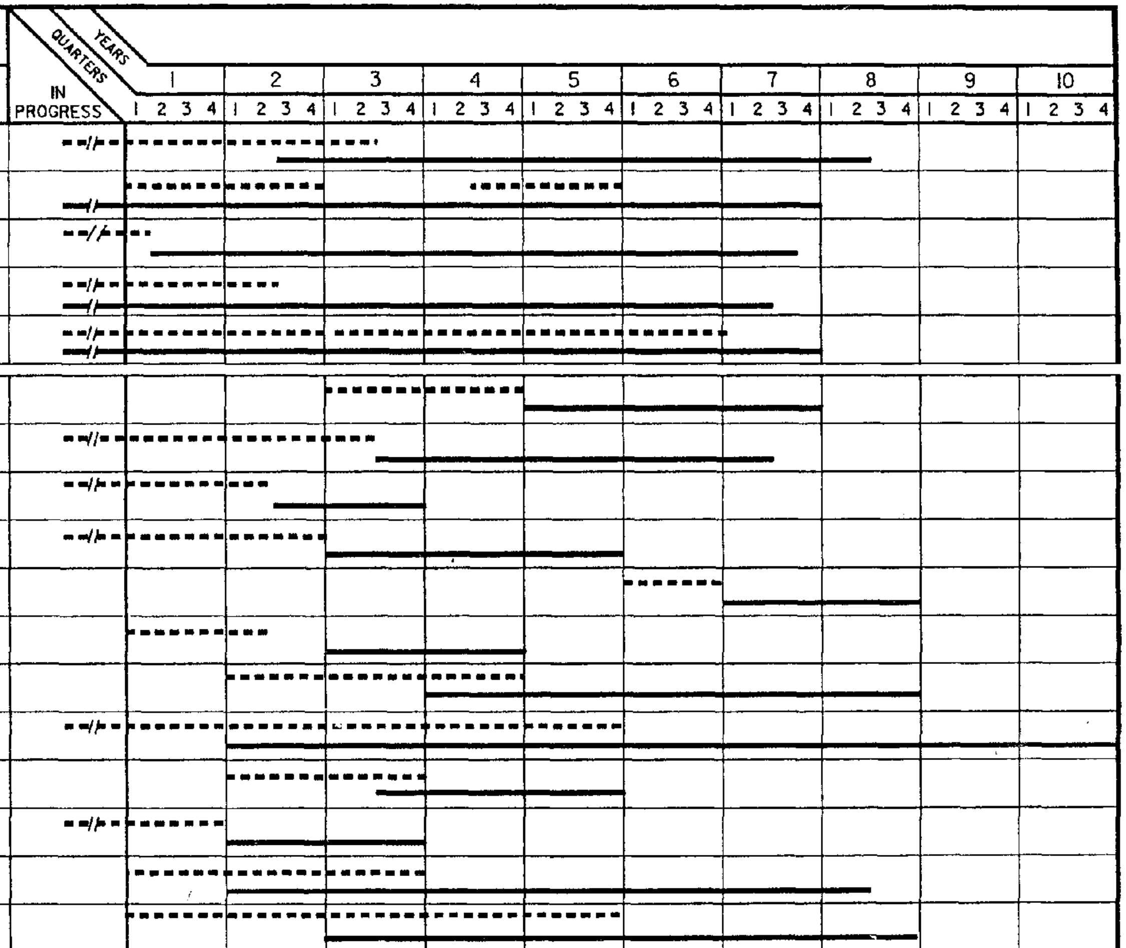
LEGEND

- ▪▪▪▪▪ ENVIRONMENTAL PROCESS, R.O.W. ACQUISITION AND DESIGN
- ▬▬ CONSTRUCTION
- * PROJECT DETAILS ARE CONTAINED IN APPENDIX A
- † YEARLY EXPENDITURES ARE BASED SOLELY ON SEQUENCING CONSIDERATIONS AND NOT ON FUNDING AVAILABILITY

PROGRAM 3 - BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION

FIGURE 3. PROJECT COST ESTIMATES AND LOGICAL SEQUENCING FOR PROGRAM 3, BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION

	PROJECT *	ESTIMATED COST (1991 $ MILLIONS) UNFUNDED	FUNDED	TOTAL
1	N.Y. PENN STATION AND TUNNEL IMPROVEMENTS	366	9	375
2	CATENARY REPLACEMENT AND STR. REHABILITATION	350	24	374
3	PECK BRIDGE REPLACEMENT	86	23	109
4	MOVABLE BRIDGES	64	59	123
5	FIXED BRIDGES	213	5	218
6	HAROLD INTERLOCKING (EASTBOUND FLYOVER)	65	0	65
7	SHELL INTERLOCKING IMPROVEMENT	30	25	55
8	STAMFORD STATION - ISLAND PLATFORMS	30	0	30
9	NEW HAVEN STATION - YARD/APPROACH	55	5	60
10	NEW HAVEN - NORWALK, 4th TRACK	20	0	20
11	CANTON VIADUCT	9	1	10
12	TRACK IMPROVEMENTS	214	6	220
13	SIGNAL SYSTEM UPGRADES	44	56	100
14	GRADE CROSSING IMPROVEMENTS	10	0	10
15	STATIONS	32	1	33
16	NEW HAVEN - BOSTON ELECTRIFICATION	445	25	470
17	CURVE REALIGNMENTS	715	0	715
	TOTALS	2,748	239	2,987



YEARLY EXPENDITURE † (1991$ MILLIONS)	IN PROGRESS	1	2	3	4	5	6	7	8	9	10
	239	140	271	433	435	439	405	389	220	8	8

LEGEND

▪▪▪▪▪ ENVIRONMENTAL PROCESS, R.O.W. ACQUISITION AND DESIGN

▬▬▬ CONSTRUCTION

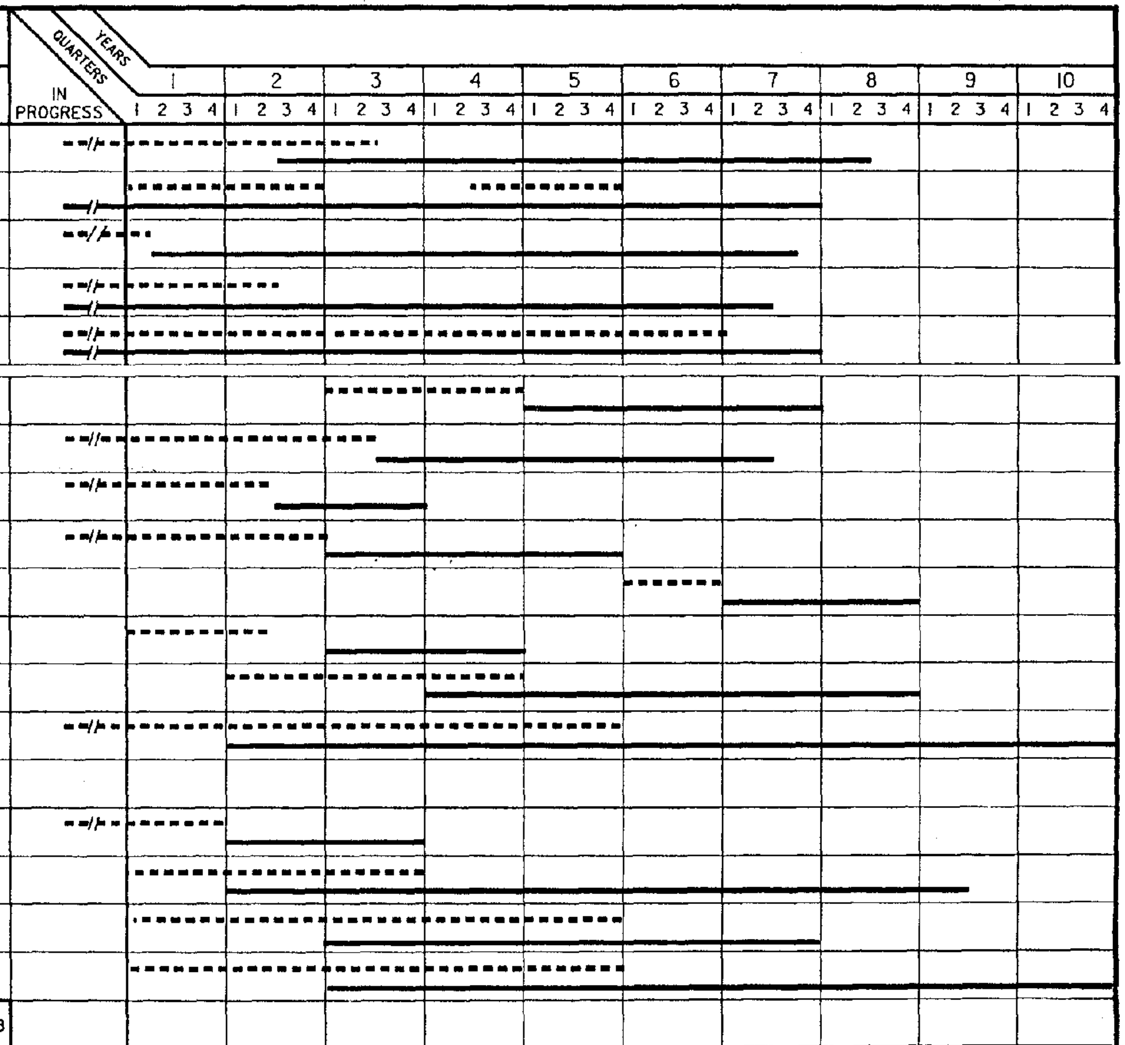
* PROJECT DETAILS ARE CONTAINED IN APPENDIX A

† YEARLY EXPENDITURES ARE BASED SOLELY ON SEQUENCING CONSIDERATIONS AND NOT ON FUNDING AVAILABILITY

PROGRAM 4 - ALL SYSTEM IMPROVEMENTS AND ELECTRIFICATION

FIGURE 4. PROJECT COST ESTIMATES AND LOGICAL SEQUENCING FOR PROGRAM 4, ALL SYSTEM IMPROVEMENTS AND ELECTRIFICATION

	PROJECT *	ESTIMATED COST (1991 $ MILLIONS) UNFUNDED	FUNDED	TOTAL
1	N.Y. PENN STATION AND TUNNEL IMPROVEMENTS	366	9	375
2	CATENARY REPLACEMENT AND STR. REHABILITATION	350	24	374
3	PECK BRIDGE REPLACEMENT	86	23	109
4	MOVABLE BRIDGES	10	59	69
5	FIXED BRIDGES	213	5	218
6	HAROLD INTERLOCKING (EASTBOUND FLYOVER)	65	0	65
7	SHELL INTERLOCKING IMPROVEMENT	30	25	55
8	STAMFORD STATION - ISLAND PLATFORMS	30	0	30
9	NEW HAVEN STATION - YARD/APPROACH	55	5	60
10	NEW HAVEN - NORWALK, 4th TRACK	20	0	20
11	CANTON VIADUCT	9	1	10
12	TRACK IMPROVEMENTS	214	6	220
13	SIGNAL SYSTEM UPGRADES	44	56	100
14	GRADE CROSSING IMPROVEMENTS (BYPASSED)	0	0	0
15	STATIONS	32	1	33
16	NEW HAVEN - BOSTON ELECTRIFICATION	445	25	470
17	CURVE REALIGNMENTS EXCEPT BYPASS ALIGNMENT (OLD SAYBROOK - BRADFORD)	450	0	450
18	BYPASS ALIGNMENT (OLD SAYBROOK - BRADFORD)	1,180	0	1,180
	TOTALS	3,599	239	3,838



YEARLY EXPENDITURE † (1991 $ MILLIONS)	IN PROGRESS	1	2	3	4	5	6	7	8	9	10
	239	152	281	567	566	560	509	488	252	146	78

LEGEND

- - - - - ENVIRONMENTAL PROCESS, R.O.W. ACQUISITION AND DESIGN
——— CONSTRUCTION

* PROJECT DETAILS ARE CONTAINED IN APPENDIX A

† YEARLY EXPENDITURES ARE BASED SOLELY ON SEQUENCING CONSIDERATIONS AND NOT ON FUNDING AVAILABILITY

PROGRAM 5 - SHORE LINE BYPASS

FIGURE 5. PROJECT COST ESTIMATES AND LOGICAL SEQUENCING FOR PROGRAM 5, SHORE LINE BYPASS

1. INTRODUCTION

> *"Now that the Washington-New York portion of the Northeast Corridor has been improved, we need to turn our attention to the New York-Boston segment. Facilities and services need to be upgraded to improve the travel time on the Boston-New York run and to enhance the commuter systems that share the right-of-way with Amtrak. Speedy and reliable service would encourage more passengers to use the trains and this could help to relieve some of the congestion in the major airports in the Northeast."*
>
> --Samuel K. Skinner,
> Secretary of Transportation

1.1 BACKGROUND

The Northeast Corridor--the 456-mile system of railroad passenger service infrastructure which extends from Boston to Washington, DC--serves one of the most populous and heavily travelled regions of the United States. With New York City at its midpoint, and including seven major urban areas with a total population of almost 40 million, the region served by the NEC has long made effective use of rail passenger transportation. In addition to the necessity of assuring the continued ability of the Corridor to fulfill its critical role in commuter travel, the need for the fullest exploitation of all intercity transportation alternatives is readily apparent: cumulative annual delays exceed 20,000 aircraft hours for six of the seven major airports serving the region, and highways near the urban centers are often severely congested.

In the 1970s and 1980s the Northeast Corridor Improvement Program (NECIP) spent $2.5 billion upgrading the rail infrastructure of the NEC. Service approaching 2½ hours for travel between New York and Washington contributed to Amtrak's capturing nearly one-half of the common carrier market on that route. However, plans for the Boston-New York portion of the corridor had to be modified as a result of escalating costs, limited funds, lack of electrification for more than two-thirds of the distance, and a more curve-intensive route alignment. Ambitious goals and program elements were substantially scaled back, exemplified by elimination of planned electrification from New Haven to Boston. Major replacement and rehabilitation projects identified 20 years ago have yet to be implemented. As a consequence, the shortest scheduled time between Boston and New York is now just under 4 hours, too long to attract the time-sensitive business travellers who represent a large portion of intercity travel in the region.

In addition, continued growth in airport and highway congestion, coupled with rising attention to environmental and other social impacts of transportation, has led to a renewed interest in the potential role of the Boston-New York half of the NEC in meeting the intercity travel needs of the region. This interest is particularly appropriate in the context of the Administration's National Transportation Policy, which has as its first major theme "maintain[ing] and expand[ing] the nation's transportation system."

The Corridor is also highly relevant to the second theme of the NTP: "Foster[ing] a sound financial base for transportation." Approximately one-half of Amtrak's passengers and more than one-third of its passenger revenues are associated with the NEC, and Corridor improvements could lead to a ridership growth contributing significantly to reduction or elimination of the current Amtrak system-wide operating deficit of approximately $343 million in 1990.

The role of the Corridor is perhaps even more important in commuter transportation than for intercity travel. Metro-North Commuter Railroad (MNCR) carries 25 million New York and Connecticut riders annually on NEC track, more than ten times the number of Amtrak riders on that segment. MBTA commuter services extend from Boston to Providence, and the Connecticut Department of Transportation (CDOT) has recently initiated service between New Haven and Old Saybrook. The Long Island Rail Road shares only a small portion of the Corridor--4 miles from Queens into Pennsylvania Station--but over 400 commuter trains per day operate on that segment.

All of these agencies expect continuing ridership growth in the future. The need for further rehabilitation to assure the reliability and growth of commuter rail services has been clearly documented. Thus, a study of the NEC must include full consideration of the interaction between commuter and intercity services, and the impact of Corridor improvements on commuters and operators.

Associated with the broad extent of commuter operations on the NEC is a complex structure of institutional and financial relationships which bear directly on the process of formulating and implementing public decisions regarding the Corridor. For example, Amtrak owns only approximately 60% of the track miles; other sections are owned by commuter authorities or states, with Amtrak operating under rights pursuant to the Rail Passenger Service Act of 1970. The commuter operations are funded substantially by State agencies or Transit Authorities, with some of the support originating with the Urban Mass Transportation Administration (UMTA). On the other hand, Amtrak's operating subsidy and capital improvement appropriations are administered by the Federal Railroad Administration (FRA). The basic ownership and institutional structure of the New York-Boston half of the Corridor is described in Section 3.

The same success for the Boston-New York rail travel achieved for intercity services between New York and Washington would be a major undertaking. Much of the Corridor's fixed plant--bridges, tunnels, catenary, Pennsylvania Station--is at least 80 to 90 years old. As early as the 1970s, the decline of rail passenger service had been accompanied by an extensive deterioration of infrastructure. NECIP expenditures addressed a substantial portion of this problem, but by no means all. Whether or not any substantial effort to improve speed and quality of service is sought, a large measure of rehabilitation and replacement will be required to assure safety and bring the railroad to a state of good repair.

Basic rehabilitation alone is a daunting task. Aside from policy considerations, the magnitude of the Federal deficit and the constraints established by the 1990 Congressional budget agreement sharply limit the availability of Federal funds. All of the states through which the north end of the Corridor passes are facing similar--though even more severe--budgetary difficulties. While it is sometimes possible to finance rolling stock privately, that approach has not traditionally been used for fixed plant.

Investment in large-scale transportation infrastructure calls for a very long time horizon. The NEC is not now greatly changed in outward form and appearance from the early 1900s. Whatever improvements are brought about over the next decade or so are likely to define the Corridor for much of the 21st century. Constraints of funding, land use, and environmental impacts are unlikely to diminish in the future; on the contrary, they will likely become ever-more-restrictive barriers to the creation and modification of transportation infrastructure. Growth in commuter rail and expansion of intercity service could become increasingly incompatible as available capacity becomes saturated. Implementation of improvements will become more difficult, more expensive, and more time-consuming. Hence, it is particularly important that any NEC investment decisions in the 1990s, including decisions not to invest, reflect a very long-term perspective and be based on a thorough and comprehensive study of needed rehabilitation and improvements.

In 1990, Secretary Skinner initiated a study of this nature. The study was performed by the Department of Transportation's John A. Volpe National Transportation Systems Center. A Departmental Task

Force led by Federal Railroad Administrator Gil Carmichael and Urban Mass Transportation Administrator Brian Clymer was established to oversee the work. This report contains the results of that effort. Its central focus is ways in which commuter rail and intercity trip time and reliability can be improved through fixed plant investment, but operational, institutional and financial considerations are also addressed.

1.2 OBJECTIVES OF THE STUDY

The overall objective of this study is to provide a comprehensive characterization of potential fixed-plant improvements which could be made to the portion of the Northeast Corridor running from New York City to Boston. The improvements are delineated in terms of their cost, travel time gains and other benefits, priority, schedule and sequencing, and relevant financial and institutional factors. The broader purpose of the study is to create a solid foundation of information to support formulation of public policy regarding future NEC investments.

The study addresses the following questions:

- What fixed-plant improvements are needed to assure safety or replace infrastructure elements which have reached the end of their normal service life?
- What could be done to the NEC fixed-plant infrastructure to achieve substantially faster and more reliable rail service?
- How much would these improvements cost?
- What degree of intercity trip time improvement is attainable for various levels of capital investment?
- How do the trip time impacts of specific improvements depend upon the intercity rolling stock used?
- What impact would various levels of improvement have on intercity ridership?
- To what degree would increased intercity ridership be drawn from people who would otherwise have used air or highway modes?

- o How would the time savings and service improvements be distributed among commuters and intercity passengers?

- o What are the institutional considerations or constraints that affect the degree to which improvement projects yield the intended trip time and service gains?

- o What would be a logical sequence of improvement projects within each alternative program?

- o What funding sources and mechanisms are potentially relevant to Corridor improvements?

Two broad classes of improvements are considered: (1) projects necessary for continued system safety or to bring the system to an overall state of good repair; and (2) system improvement projects yielding better service for riders. A key service improvement sought is a substantial reduction in trip time; a Boston-New York schedule under 3 hours is widely thought to be necessary for rail to compete successfully with airlines for business travel. However, speed alone would not be sufficient to obtain the transportation goals sought. Service reliability and frequency and a high level of ride quality are also necessary elements for a successful rail transportation system.

Individual projects are characterized and are then grouped into five programs: a System Rehabilitation Program plus four system improvement programs, each successive program adding projects that yield a shorter trip time but necessarily incur a higher cost.

A central concern is the interaction between intercity and commuter operations. The study explicitly considers the benefits and impacts of candidate improvement projects on the commuter railroads which share and own portions of the NEC, with the aim of improving performance and reliability for all Corridor users.

1.3 SCOPE OF THE STUDY

This study provides a comprehensive and consistent picture of the Corridor and its potential performance, presented at a level to support broad policy development. It combines results of prior studies, analyses and estimates by the involved public agencies, operating railroads, and others. It generally does not address details of the design or implementation of specific projects, nor does it critique the past decisions or actions of organizations which own segments of the Corridor or operate rail services on it. Only capital costs for rehabilitation and service improvement projects are considered; this study is not an economic analysis of corridor operations, and does not address operating and maintenance costs.

1.3.1 Rolling Stock

The study focuses on fixed plant capital investment. However, the trip time which would be attainable for a given program of improvements depends significantly on the rolling stock used. Trip time estimates developed in this study assume equipment now available.

1.3.2 Service Quality

Reliable service--a high percentage of on-time performance and avoidance of lengthy delays--is closely related to perceived trip time and is a critical factor in the viability of rail passenger service. Improvement projects which address reliability are thus an essential component of this study. Acceptable reliability cannot be achieved in a congested system, so projects contributing to adequate capacity are also required.

A high level of ride quality is also a necessity, so roadbed projects such as track and bridge improvements which advance this goal are addressed. Other service quality and passenger comfort factors that can bear strongly on the viability of intercity rail service--such as station amenities, on-board conveniences, pricing strategies, scheduling, and marketing--are not within the scope of this study.

1.3.3 Funding Sources

Funding for the Northeast Corridor Improvement Program of the 1970s and 1980s was provided by the Federal government through the FRA, but there have also been very substantial State and UMTA expenditures, primarily in commuter service capital grants, over that time. The study is charged with identifying possible funding sources--particularly those involving the private sector, users, and state and local government--in order to clarify the means by which improvement programs might be funded. However, recommendations for funding responsibilities or allocations are not within the scope of this analysis.

In terms of the number of individual passengers benefitting, some of the potential Corridor improvement projects--particularly between New York and New Haven--will affect many more commuters than intercity travellers. It is not within the scope of this study to determine the "fair share" of program cost which should be borne by commuter agencies and UMTA as compared to FRA or Amtrak directly. However, in order to provide background information that could be relevant to determining an allocation of funding responsibilities, the study does include a very approximate characterization of projects in terms of their separate importance to intercity and commuter service, and indicates the current number of intercity and commuter passengers likely to be affected by each project.

1.3.4 Benefit Analysis

A wide range of societal benefits could be expected from substantially improved Boston-New York rail service. The most direct benefit of a shorter trip time is increased ridership, and that measure is used in this study, along with estimates of time savings for commuters as well as intercity passengers. Two closely related consequences are diversion of travellers from congested airports and highways, and increased Amtrak net revenues that permit a reduced Federal operating subsidy. These benefits are real, though difficult to quantify precisely, and are addressed in the study.

Several other classes of benefit are often described: reduced environmental impacts--primarily air pollution--due to the diversion from less environmentally benign modes; energy and petroleum savings; stimulation of economic development; avoidance of infrastructure investment in new or expanded highways and airports; increased efficiency and reduced maintenance cost for a renewed rail infrastructure; and enhanced personal mobility for residents of the Northeast. These benefits, legitimate in concept, depend on so many assumptions and are so difficult to assess quantitatively that they are not addressed in this study.

1.3.5 Principal Assumptions

Time Frame: The basic time period during which project implementation would occur is 1991-2000. Some projects, such as a new bridge over the Pequonnock River, have already been initiated. In view of the very long service life of properly maintained rail infrastructure, as well as the need to allow travel patterns in New England to adjust to the availability of improved service, the nominal year used for ridership projections is 2010.

Route/Right-of-Way: The study primarily considers improvements that can be made within the current route and right-of-way. Generally, significant deviation from that route would involve extremely severe issues of land use, cost, and environmental impacts; alternative alignments have typically not been found to be viable in the past.

Amtrak has recently conducted a preliminary examination of an alternative route from Old Saybrook, Connecticut to Kingston, Rhode Island, a 50-mile 150 MPH alternative route segment which would eliminate the movable bridges and many curves that now constrain speed along the Connecticut and Rhode Island coast. Based on the interest shown by Amtrak, this project is included in the study.

Technology: The basic technology of railroad fixed plant is quite mature. Cost estimates are based on existing equipment and techniques. Conventional rolling stock is assumed, which includes not only equipment that can be purchased today, but also locomotives, cars, and trainsets that have completed development and testing and will soon be on the market.

Magnetic levitation technology is not considered. This results not only from its early state of development, but also because of its difficulty in sharing a tightly constrained right-of-way with commuter rail operations, the extreme problem of access to Manhattan, and the very large number of curves which would preclude making use of the high maximum speed claimed for magnetic levitation.

Trip time estimates for each improvement program are calculated for several rolling stock choices. In each case, the simulations are based on hypothetical trains matching the key parameters (e.g., power-to-weight ratio) of equipment now in service or available. This study does not attempt to characterize in detail motive power and coach or trainset alternatives. Neither does it distinguish among alternative realizations of specific technology, such as different lightweight electric trains or tilt-suspension coaches.

Speed on Curves: Just as for other surface modes, curved railroad track is often banked to permit higher speed than would otherwise be suitable. In railroad terminology, the distance by which the outer rail is elevated above the level of the inner rail is called "superelevation," and is typically measured in inches. The "balance speed" for a given curve is the speed at which the centrifugal force is exactly balanced by the inward component of gravitational force associated with the superelevation. Federal regulations permit trains to operate at a speed that would be balanced if there were 3 additional inches of superelevation; this condition is commonly referred to by several equivalent terms: "3 inches of unbalance," "3-inch underbalance," or "3-inch cant deficiency." The FRA can approve operations above 3 inches of unbalance, and has granted waivers for 4-inch and 5-inch unbalance at some locations between New Haven and Boston.

In some countries, high-speed service operates at unbalance exceeding 8 inches. Many experts feel that with appropriate track standards and suitable rolling stock, use of 6-inch unbalance for curves with 6-inch superelevation (thus permitting speeds equal to the balance speed for 12-inch superelevation) may be fully acceptable in terms of safety and passenger comfort. Refinement of these standards and determination of curve speeds for which waivers can be approved on the NEC would be part of any improvement program.

In this study, the upper limit on curve speeds, when track quality permits and other constraining factors are not present, is based on 6-inch superelevation and 6-inch unbalance, for a total of 12 inches. Factors which can reduce this limit in practice include overhead catenary geometry, distance available for spiral transition from tangent track into the curve, proximity of station platforms, and spacing between tracks. It is further assumed in this analysis that tilt-suspension coaches could operate at 8-inch unbalance, or 14 inches including the superelevation. This result is consistent with prior limited testing but subject to extensive future testing and analysis to establish acceptability.

2. APPROACH

2.1 OVERVIEW

The basic sequence of activities comprising this study is indicated in Figure 2-1. Information relevant to NEC improvements was acquired and analyzed in terms of specific projects and system aspects. As indicated in the figure, four types of technical analysis were involved in performing these tasks: engineering, operational, financial, and institutional. Based on the project-level analysis, a set of alternative overall improvement programs, representing a hierarchy in terms of both cost and performance, were developed by grouping appropriate projects. Each resulting program was then analyzed in detail as to trip time, projected ridership gain, logical sequencing of projects, and other characteristics.

The core of the study lies in the specific analysis tasks shown in Figure 2-2. These figures show a compartmentalized structure, but within that general framework the study embodied a highly iterative, synergistic and interactive process, in which new information was often relevant to several analysis tasks and generated new questions or data requirements in each. Each phase of the study, as diagrammed in Figure 2-2, is described briefly below.

2.2 ACQUISITION OF INFORMATION AND IDENTIFICATION OF POTENTIAL IMPROVEMENTS

The initial phase consisted of two primary activities: (1) review of relevant documents from the very extensive literature generated by the NECIP and subsequent undertakings; and (2) development of contacts and effective working relationships with the various organizations and agencies with relevant experience, information, understanding, and interests.

2.1.1 Literature Review

One by-product of the original Northeast Corridor Improvement Program and related undertakings was a very large number of documents. A great many of these are of a highly detailed nature, often relating to activities long since completed. The much-more-limited selection of documents that have proven of special value to this study are listed in the bibliography. Primary references include reports prepared by the High-Speed Rail Task Force of the

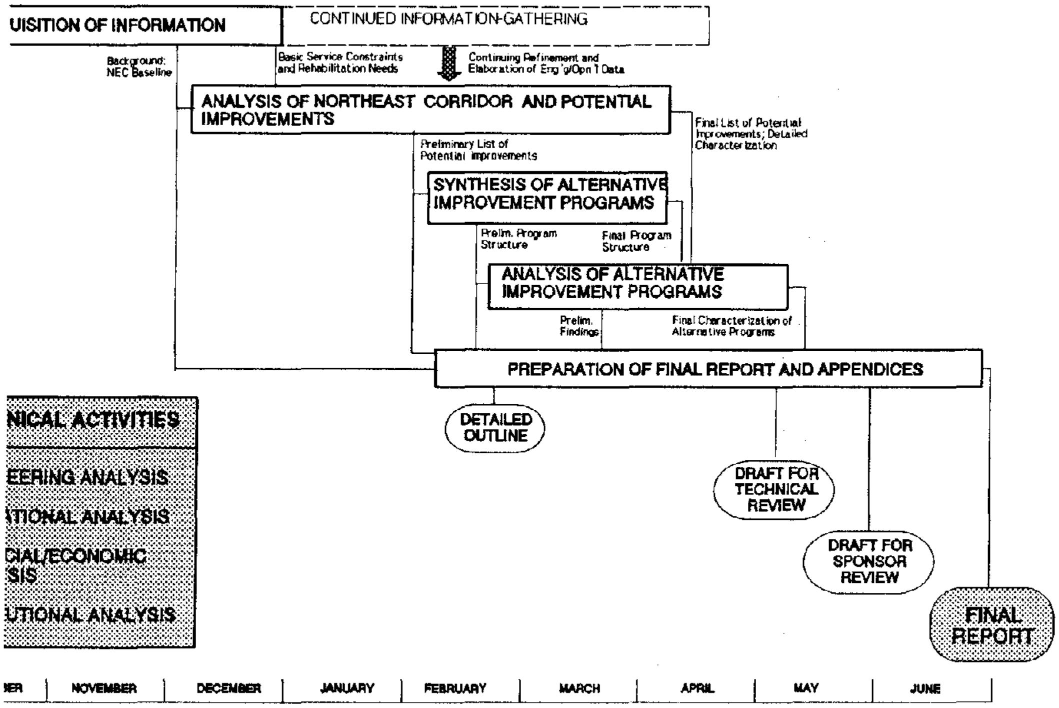


FIGURE 2-1. MAJOR STUDY ACTIVITIES

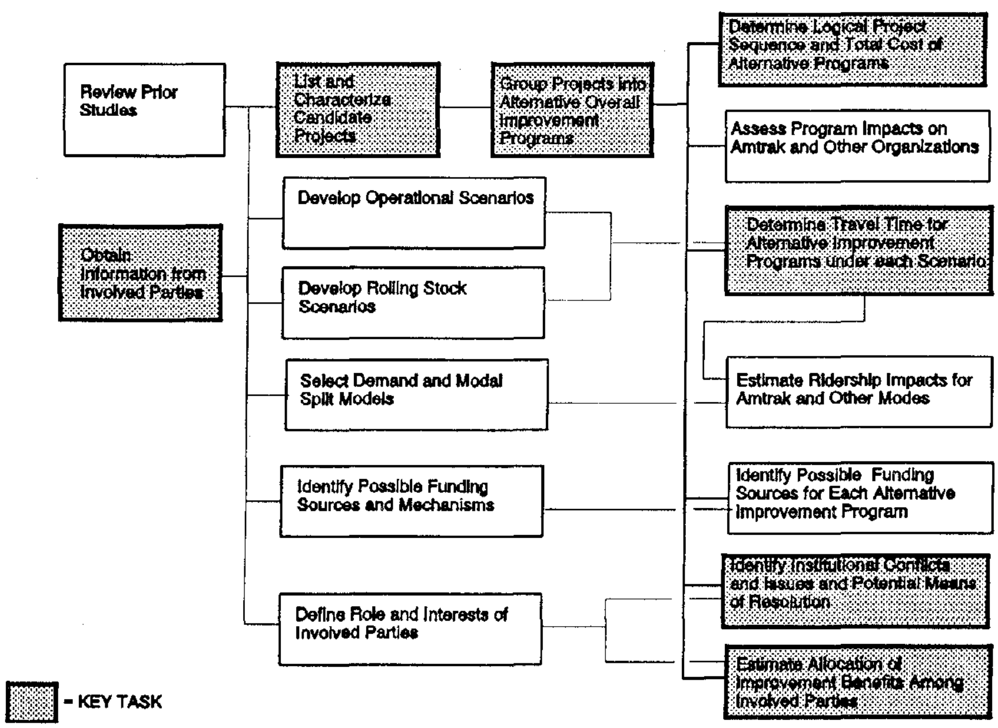


FIGURE 2-2. MAJOR SPECIFIC STUDY TASKS

Coalition of Northeastern Governors (CONEG), which in recent years has been a major proponent of rail service improvements and an active participant in associated activities.

2.2.2 External Contacts

Many organizations own, operate, use, or are strongly affected by the Northeast Corridor, and their participation and active cooperation was critical to the study. Developing a good working relationship with them was a key activity. In addition to extensive participation by knowledgeable individuals at UMTA and FRA, organizations which provided information and comment include:

- Amtrak
- Metro-North Commuter Railroad (MNCR)
- Long Island Railroad (LIRR)
- Massachusetts Bay Transportation Authority (MBTA)
- [New York] Metropolitan Transportation Authority (MTA)
- Connecticut Department of Transportation (CDOT)
- Massachusetts Executive Office of Transportation and Construction
- Rhode Island Department of Transportation (RIDOT)
- New York Department of Transportation (NYDOT)
- Conrail
- Providence & Worcester Railroad (P&W)
- Northeast Corridor Commuter Rail Authorities Committee (NECCRAC)
- Coalition of North Eastern Governors (CONEG)

Participation of these organizations was initially requested in a letter jointly signed by the UMTA and FRA Administrators. Contacts typically began with an introductory meeting, in which the purpose of the study was described, the external organization clarified its role and particular areas of knowledge and interest, and general information was requested. Based on the cumulative information gained from literature and meetings, requests for specific information were made to each organization, additional meetings were held, and in some cases site visits or observation-car trips were provided. As draft documentation was developed concerning technical details of the potential improvement projects and their impacts, it was provided to these organizations for comment. This phase of the study provided the information base and understanding necessary for the three core phases which followed.

2.3 ANALYSIS OF NEC AND POTENTIAL IMPROVEMENTS

The literature search and external meetings provided a broad perspective on the factors which constrain trip time on the Corridor, and also identified numerous candidate rehabilitation and service improvement projects. Many of these projects had a long history, often having been deferred repeatedly due to funding limitations. The Corridor was also examined in a "top down" manner. A particularly useful exercise, conducted jointly with FRA, Amtrak, and Metro-North, was a detailed review of the entire route, focused on assessing the highest operating speed likely to be achievable on each curve, assuming maximum superelevation and cant deficiency. While various other factors often impose additional constraints, as described above, this provided an upper bound and a target for improvements.

Special attention was devoted to understanding the constraints associated with intercity and high-density commuter services sharing some portions of the route. Consideration was also given to the complexities of designing and implementing improvements which affect commuter as well as intercity services, and to defining the likely role of each party in implementation.

This phase of the study also included a limited but careful review and validation of the engineering cost estimates for the various projects. In cases where no recent preliminary design studies had been performed, independent cost estimates were developed.

The principal product of this phase was characterization of all candidate projects, provided in Appendix A, Profiles of Candidate NEC Improvement Projects.

2.4 SYNTHESIS OF ALTERNATIVE IMPROVEMENT PROGRAMS

The project characterizations included estimates of cost, approximate potential contribution to faster schedules, and interrelationships among the projects. In the Program Synthesis phase the projects became the building blocks from which alternative overall programs, varying in cost and resulting trip time performance were constructed.

This phase of the study defined the program alternatives so that a detailed analysis of the performance, ridership impacts, and logical implementation sequence could then be performed.

2.5 ANALYSIS AND CHARACTERIZATION OF ALTERNATIVE IMPROVEMENT PROGRAMS

This phase of the study yielded the "bottom line" of the entire undertaking: the total cost and potential trip time for each program alternative, and an estimate of the ridership increases and other benefits which might result. Program cost was determined by summing estimates for the individual projects. Speed improvements were determined by defining the route profile of maximum authorized speeds appropriate to each improvement program, selection of rolling stock scenarios and execution of train performance calculations to determine trip time. Estimation of the ridership and other benefits which would be achieved for the projected trip times were based on sophisticated demand models.

Other topics addressed in this Program Characterization phase included determination of the logical sequencing of projects within a program, estimation of the relative allocation of benefits of greater speed and reliability between commuters and intercity passengers, and means of achieving a true system-level perspective and facilitating coordination and cooperation among the various institutions which would be involved in implementation and operation of services along the improved Corridor.

2.6 PREPARATION OF FINAL REPORT AND APPENDICES

The results of each of the phases and tasks are documented in this Final Report, with details provided in four technical appendices.

3. NEC DESCRIPTION AND HISTORY

3.1 DESCRIPTION OF THE NORTHEAST CORRIDOR

The Northeast Corridor consists of 456 route miles of railroad running from Washington, D.C., through New York City to Boston. Other connecting routes are often considered as elements of the Corridor, including segments between Springfield, Massachusetts and New Haven; between Albany and New York City; between Philadelphia and Atlantic City; and between Philadelphia and Harrisburg. It is often convenient to further divide the Corridor into the "south end"--Washington-New York (225 miles)--and the "north end"--New York-Boston (231 miles). In this document, references to the NEC generally allude to the portion of the core route between New York City and Boston unless otherwise indicated.

The overall Corridor passes through one of the most-densely populated and urbanized sections of the United States, which includes eight states and the District of Columbia. Several of the nation's largest cities are located along the Corridor, including Boston, New York City, Philadelphia, Baltimore and Washington, D.C. Smaller urban centers located on the Corridor include Providence, New Haven, Trenton, and Wilmington. Together, these metropolitan areas contain nearly 40 million persons, or nearly one-sixth of the entire U.S. population.

Intercity and commuter rail passenger service on the Corridor is extensive--perhaps the densest in the entire nation. For example, the full Boston-Washington Corridor carries approximately one-half of Amtrak's total annual passenger volume. Eight different local or regional transportation authorities are involved in the provision of commuter rail services, which share more than one-half of the entire Corridor's length with Amtrak trains. In contrast, freight service along the Corridor is declining, and is primarily limited to serving existing local customers.

Prior to 1970, the Corridor was owned and operated by a number of private railroad companies operating both passenger and freight service. Shortly after the Second World War, however, passenger volume began a steady decline, as did the economics of freight rail service. In both cases, mounting competition from road and air transportation was a major factor. Finally, in the face of the bankruptcies of Northeastern railroads and the consequent elimination of the region's rail infrastructure, Congress passed a series of laws in the early 1970s to reorganize the freight and passenger rail systems. As part of this legislation, ownership and operation of the Corridor was eventually vested in several authorities.

Table 3-1 presents an overview of the resulting web of institutional responsibilities along the Corridor between New York City and Boston. Although relationships among the various owners and users are generally harmonious, the various parties have differing perspectives, functions, and constraints. The result is that no single organization is explicitly responsible for assuring that this valuable segment of the nation's transportation infrastructure is used in a coordinated way that best serves all elements of the travelling public and the national economy.

TABLE 3-1. INSTITUTIONAL RESPONSIBILITIES FOR THE NORTHEAST CORRIDOR BETWEEN NEW YORK CITY AND BOSTON

From	To	Distance (miles)	Owner	Maintenance	Dispatching	Commuter Operations	Commuter Authority	Freight Service
Penn Station	Harold Interlocking	4	Amtrak	Amtrak	Amtrak	LIRR	MTA	--
Harold Interlocking		--	LIRR	LIRR	LIRR	LIRR	MTA	--
Harold Interlocking	Shell Interlocking	15	Amtrak	Amtrak	Amtrak	--	--	Conrail
Shell Interlocking	NY-CT State Line	10	MTA	MNCR	MNCR	MNCR	MTA	Conrail
NY-CT State Line	New Haven	46	CDOT	MNCR	MNCR	MNCR	CDOT	Conrail
New Haven	Old Saybrook	33	Amtrak	Amtrak	Amtrak	Amtrak	CDOT	Conrail
Old Saybrook	RI-MA State Line	86	Amtrak*	Amtrak	Amtrak	--	--	P&W
RI-MA State Line	Boston	38	MBTA	Amtrak	Amtrak	Amtrak	MBTA	Conrail

* RI DOT owns approximately 1/4-mile of track through and adjacent to Providence Station.

3.2 HISTORICAL OVERVIEW

The Corridor, and much of its existing fixed plant, has long been an important element of the transportation infrastructure of the Northeast. The current situation can best be understood in the light of that history.

3.2.1 Early History of the Corridor

As the early economic and population center of the nation, the Northeast was serviced by railroads as soon as that technology became available. For example, the construction of railroad track between Boston and Providence dates from the 1830s. The Canton viaduct, which still carries rail traffic on the Corridor in eastern Massachusetts, was originally built in 1836. The first rail connections between Washington, New York City and Boston were completed by 1858. Many of the movable and fixed bridges along the route through Connecticut were built between the Civil War and the First World War, replacing the previous ferry links for rail passengers across the river mouths. By 1918, the Corridor as we now know it was essentially complete.

Two major segments of the route were electrified early in this century. The New York, New Haven and Hartford Railroad electrified the "New Haven Line" between New Haven and New York City in the decade before the First World War, and the Pennsylvania Railroad electrified the southern half of the Corridor in the 1930s. Much of this original infrastructure is still in service.

By the 1960s the actual infrastructure of the Corridor--track, bridges, tunnels, signals, catenary, communications, service facilities and passenger stations--represented a highly disparate collection of elements in widely varying states of repair. No major improvements had been made since the 1930s. The overall deterioration in the condition of the Corridor, especially in the years during the nationwide decline of rail passenger service after World War II, led to service that was increasingly slow and unreliable.

3.2.2 Modern History of the Corridor

The earliest direct Federal role in improving rail travel in the NEC came in 1963 with a modest ($625,000) appropriation initiating a Northeast Corridor Project within the Department of Commerce. This was followed 2 years later by the High-Speed Ground Transportation Act of 1965, which established the Office of High Speed Ground Transportation (OHSGT), also within the Commerce Department, as well as the Northeast Corridor Transportation Project. The creation of the U.S. Department of Transportation in 1967 led to the consolidation of these functions, along with the long-established Interstate Commerce Commission (ICC) Office of Railway Safety, into the new Federal Railroad Administration (FRA).

From its inception, OHSGT was chartered to sponsor research, development, and demonstration of high-speed rail technology. One result was development of the Metroliner, a self-powered electric railcar originally designed for a maximum speed of 160 MPH. Under contract with OHSGT, the Penn Central Railroad began operation of 50 Metroliners between New York and Washington in 1969. Although track limitations and mechanical problems prevented operation at speeds above 125 MPH, this service demonstrated that higher speed and greatly improved amenities could substantially increase ridership. In the early 1970s, deteriorating track conditions on the pre-bankrupt railroads, accompanied by equipment, unreliability seriously diminished the attractiveness of Metroliner service.

Another major initiative of OHSGT was support of the 1969 introduction of two gas turbine-powered passively tilting trains, constructed by United Aircraft and based on aerospace technology, between Boston and New York. Although they demonstrated good performance (a record time of 3:44) and drew increased ridership, the Turbo-Trains, like the Metroliners, suffered from poor reliability and could not overcome the limitations of deteriorated track. They were retired in 1976, by which time track conditions had lengthened their running time to 4:15.

The continuing decline of intercity rail passenger service through the 1960s, imposing an increasing burden on the primarily freight U.S. railroads, led to passage of the Railway Passenger Service Act of 1970. This legislation created the National Railroad Passenger Corporation--Amtrak--to operate almost all intercity passenger rail service in the nation.

The next major legislative action was the Regional Railroad Reorganization Act of 1973--the "3R Act"--which consolidated seven near-bankrupt Northeast and Midwest freight rail operations into Conrail, a Federally chartered freight railroad. This act also authorized the Secretary of Transportation to study possible improvements in the NEC. This was followed by the Railroad Revitalization and Regulatory Reform Act of 1976--the "4R Act"--which, while primarily concerned with freight railroads, authorized substantial funding for the Northeast Corridor Improvement Program (NECIP) to promote faster train service between Washington, New York City, and Boston.

Two important events followed the passage of the 4R Act. First, ownership of most of the NEC right-of-way and operations of intercity train service along this track were transferred to Amtrak and state transportation authorities. Second, many of the bankrupt freight and commuter rail operations along the Corridor were transferred to Conrail.

Subsequent major legislative action was the Northeast Rail Services Act of 1981 (NERSA). NERSA, among other things, allowed Conrail to divest itself, effective January 1, 1983, of its responsibilities under the 3R Act to operate commuter services. Under its provisions, MTA, CDOT and the other NEC commuter authorities operating within the eight states and the District of Columbia elected to provide for commuter services independently.

3.2.3 Improvement Program Chronology

The 4R Act of 1976 authorized $1.75 billion for NECIP to promote faster service on the Corridor. The original NECIP plan that appeared in April 1977, called the "Baseline Implementation Master Plan" or "BLIMP," identified a total of $3.5 billion worth of potential projects needed to meet 3R Act trip time requirements by reducing total Washington-to-Boston trip times by 2 hours--from 8 hours, 20 minutes to 6 hours, 20 minutes. Major improvements envisioned in this plan were:

- Over 300 curve realignments, 4 flyovers and replacement or repair of more than 750 bridges;
- 1,350 miles of new concrete or wooden ties and continuously welded rail, and 900 miles of track and interlocking improvements;
- Upgrades and extensions of the existing electric power, communications and signaling systems, including electrification from New Haven to Boston; and
- Building or rehabilitating 15 passenger stations and installing 895 miles of fencing, along with eliminating 57 grade crossings, and improving tunnels and service facilities.

Although it represented a comprehensive approach to upgrading the Corridor, the BLIMP was estimated to cost double the funding authorized at the time. Therefore, the BLIMP was succeeded in August of 1977 by an "Implementation Master Plan," or "IMP," which substantially reduced the scope of the work and cut the total cost to about $1.75 billion. The reduction was accomplished primarily by a general scaling back of activity in all categories, particularly curves, track and bridge upgrades, stations and service facilities.

Three later revisions of the overall program in 1979, 1980, and 1981 made several adjustments to various project categories. By the time of the February 1981 "Restructured Project," total appropriated NECIP funding had stabilized at $2.19 billion. Appropriations did not reach the final NECIP authorization limit of $2.5 billion until 1990.

Much was accomplished with the $2.5 billion in Federal funds made available under the NECIP program. For example, between 1977 and 1990 the following work was accomplished:

- Over 481 miles of new track and 295 miles of continuously welded rail were laid;

- Nearly 2 million new concrete and wooden ties were installed;

- 504 miles of track undercutting was accomplished;

- 49 grade crossings were eliminated;

- 22 miles of fencing was installed; and

- 13 passenger stations were built or rehabilitated.

Other significant improvements, especially in rehabilitation and upgrading, were accomplished in the Corridor's power, communications and signalling systems. However, the various successive reductions in scope resulted in a final program well short of that envisioned in the BLIMP, particularly with regard to curve realignments, rehabilitation or replacement of movable bridges, high-speed track, and grade separations at New Rochelle and Harold Interlocking. In addition, the New Haven-to-Boston electrification project was eliminated.

Because the most substantial NECIP trip time improvements were realized with the Metroliner service on the Corridor's southern half, it is normally assumed that this segment also received the great majority of NECIP funds. Actually the northern half received over 45%, or $1.1 billion, compared to $1.4 billion for the southern half. About one-third of the north end funding was expended in Massachusetts and one-third in Connecticut, with Rhode Island and New York together accounting for the remainder.

NECIP funds represent only slightly more than one-half the total public investment in the Northeast Corridor since 1970. Some of the nation's largest commuter railroads operate along the Corridor, particularly between New York and Boston: Metro-North Commuter Railroad, Long Island Rail Road, and the MBTA. These commuter rail operations receive both capital grant and operating assistance from UMTA, directly or through public agencies. All UMTA capital grants require some local or state matching funds, which can vary from 20% to 50% depending on the project.

Overall investment in the Corridor north end since 1970 is shown in Table 3-2. The four major recipients of UMTA capital grants along the Corridor are the MBTA, RIDOT, CDOT and MTA (on behalf of both MNCR and the LIRR). As shown in the table, total UMTA capital grants for commuter rail projects between 1970 and the present total $323 million, excluding funding of rolling stock. In addition, state and local sources contributed an additional $478 million in matching funds for these projects, raising the total amount to approximately $800 million.

TABLE 3-2. PUBLIC INVESTMENT IN THE NORTHEAST CORRIDOR, 1970-1990, COMMUTER AND INTERCITY, IN MILLIONS OF DOLLARS

State	Transit Funding UMTA	Transit Funding Matching	Intercity FRA/NECIP	Total Funding
Massachusetts*	$ 85 M	$ 48 M	$ 385 M	$ 518 M
Rhode Island	14	3	214	231
Connecticut	182	173	372	727
New York	42	254	167	463
Total	$ 323 M (17%)	$ 478 M (25%)	$ 1138 M (58%)	$ 1939 M (100%)

* Some portion of Southwest Corridor funding (not shown) contributed to NEC commuter rail.

Table 3-2 does not include the Southwest Corridor Project in the Boston area, which focused on relocating a rapid transit line but also involved commuter rail right-of-way rehabilitation along 5 miles of the NEC. It had a total cost of $772 million in UMTA and state funds.

When added to the NECIP funds distributed through FRA, the total Federal, state and local investment in the Boston-to-New York segment of the Northeast Corridor infrastructure since 1970 exceeds $1.9 billion. Of this amount, almost $1.5 billion (75%) was from Federal sources and nearly $500 million (25%) was from the states.

3.2.4 Trip Times

As a consequence of these projects, scheduled trip times were reduced to best values of 2½ hours for Washington-New York non-stop express Metroliner service (2:30 northbound express, 2:50 for Metroliner service with stops), and 3 hours, 55 minutes New York-Boston for the New England Express (four stops). These are comparable to the fastest schedules ever run on those routes. The then-new Metroliner MU cars achieved 2:30 from Washington to New York in 1969-70, and United Aircraft Turbotrains (requiring no engine change in New Haven and with passive tilting) operated on a

3:45 New York-Boston schedule during the same period. In the mid-1950s, the conventional Advance Merchants Limited achieved 3:55 between Boston and New York.

NECIP improvements were an important first step in recovery from a long period of deferred maintenance, and substantially improved the basic infrastructure. However, as the trip time data indicates, they did little to raise operating speeds. Further, steady growth in commuter operations has given greater importance to resolving traffic conflicts and capacity choke-points. The goal of providing a viable alternative to congested airways has long put special emphasis on speed. Thus, where the BLIMP called for a 3 hour, 40 minute service goal between Boston and New York, Amtrak and CONEG now seek trip times of 3 hours or less. Amtrak's President, Graham Claytor, has linked faster trip times along the entire Corridor to the explicit Amtrak goal of achieving operational self-sufficiency by 2000. As he stated to Congress in March 1991:

> "...infrastructure improvements to the Northeast Corridor to provide better than 2-hour, 15-minute service between Washington and New York and at least 2-hour, 59-minute service between New York and Boston will generate significant incremental revenue and ridership for Amtrak and further solidify Amtrak's predominance as the carrier of choice in the Northeast Corridor."

3.3 CURRENT AND PROJECTED NEC PASSENGER SERVICE

3.3.1 Current Service

Intercity Service: Amtrak operates 34 trains per day from Pennsylvania Station to points east and north, many of which are actually through trains on the Boston-Washington (or further) route. Twenty-four run directly between Boston and New York via the Connecticut shore and Providence. Eight other trains are routed via Hartford and Springfield. An additional train, the *Montrealer*, operates between New York City and Montreal via New London, where it diverts to northbound Central Vermont trackage.

In late 1990 Amtrak introduced the *New England Express*, which is the first train in several years to have a scheduled running time between Boston and New York of less than 4 hours. With two round trips each weekday, its scheduled trip time is 3 hours 55 minutes.

Traffic on the New York-Boston route is very important to Amtrak, although it is only a modest portion of total operations. For the year 1989, services in the Boston-New York corridor accounted for less than 8% of Amtrak's total passenger miles (450 million out of 5.7 billion miles), 10% of total riders (2.2 million out of 22 million) and less than 7% of its total operating revenue ($76 million out of $1.1 billion). The special importance of this traffic is twofold: services between Washington and Boston are among the few which now yield a positive net revenue (see Financial Aspects below), and it is a route on which very large ridership gains are possible if trip time can be reduced sufficiently.

Commuter Services: Commuter rail services make extensive use of three segments of the Corridor. The first is the 4-mile route between Pennsylvania Station and Harold Interlocking in Queens, including the East River Tunnels. This route is shared among all Amtrak service and approximately 400 Long Island Rail Road trains each weekday, although much of the LIRR traffic is on two dedicated tracks. New Jersey Transit also uses part of this route for moves of nonrevenue ("deadhead") trains from Penn Station for storage at Amtrak's Sunnyside Yard between peak periods.

The second commuter rail section of the Corridor is the 56 miles between New Rochelle and New Haven, a major segment of the Metro-North Commuter Railroad New Haven Line. MNCR operates over 200 trains each weekday along this stretch, with its highest NEC traffic between Stamford and New Rochelle. At Shell Interlocking in New Rochelle, MNCR trains branch to Grand Central Station, while Amtrak trains proceed on the Hell Gate Line to Penn Station.

MBTA's 44-mile Attleboro Line between Providence and Boston's South Station also uses the Corridor. There are nearly 130 daily MBTA revenue trains along this line, with the most traffic occurring between Canton Junction and Boston. Amtrak operates MBTA commuter service under contract.

During the summer of 1990, CDOT began the Shore Line East commuter rail service: 13 daily CDOT revenue trains along 33 miles of the Corridor between New Haven and Old Saybrook. Amtrak operates this service under contract to CDOT.

Traffic and Ridership: Figure 3-1 shows the number of daily revenue passenger trains operating along the Corridor; freight service varies from zero to five trains per day at various points, as described below. The very heavy LIRR traffic between Penn Station and Harold is not shown in this figure due to its partial separation onto dedicated commuter tracks. The figure shows only revenue trains, excluding all NJT traffic, Amtrak deadhead moves to and from Sunnyside Yard, and a significant number of nonrevenue MNCR

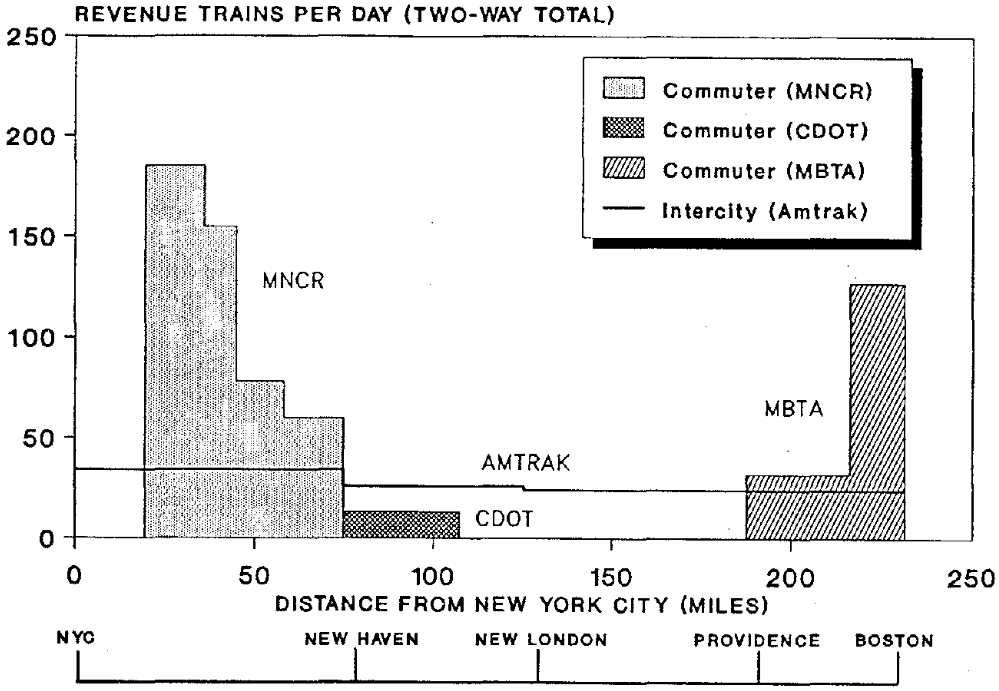


FIGURE 3-1. PASSENGER TRAINS PER DAY ON THE NEW YORK-BOSTON PORTION OF THE NORTHEAST CORRIDOR (REVENUE SERVICE TRAINS ONLY)

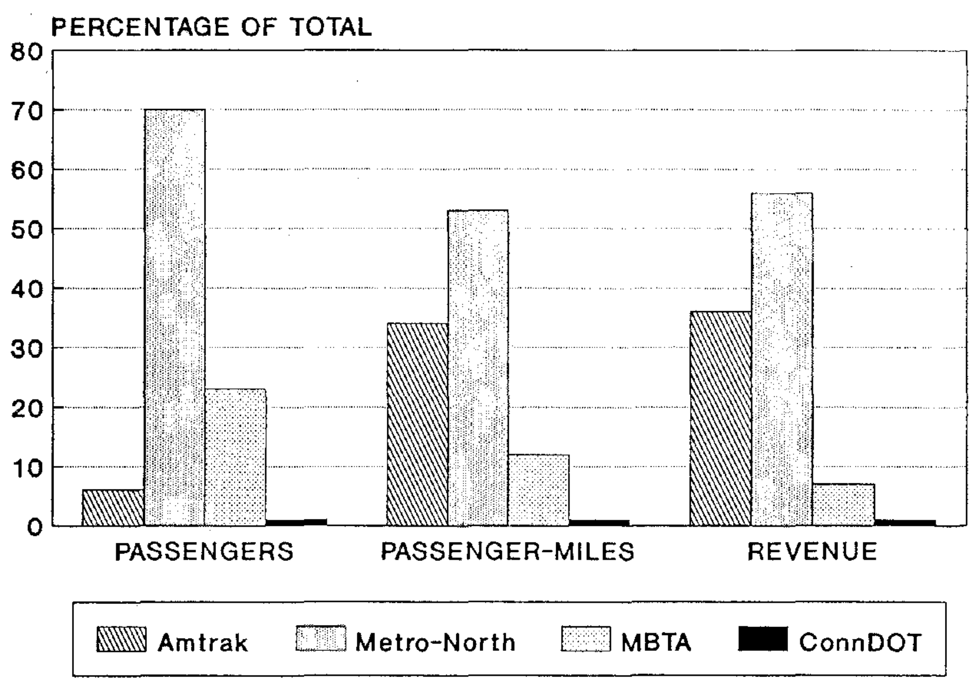


FIGURE 3-2. COMPARISON OF OPERATIONAL STATISTICS FOR PASSENGER SERVICES ON THE NORTHEAST CORRIDOR (1989 DATA)

trains. Intercity and commuter rail passengers can be seen to share about three-fifths of the Corridor's northern length.

Some overall statistics describing this shared use of the NEC are summarized in Figure 3-2, which shows the total number of passengers for Amtrak, MNCR, MBTA, and CDOT. Figure 3-2 also shows the

total passenger miles for each, and the resulting revenue. By virtually any measure, commuter rail can be seen to be the dominant user of the Corridor. For example, commuter rail passenger miles between Boston and New York totals almost 900 million per year, while, as noted above, Amtrak records a systemwide total of about 450 million passenger miles annually on the Corridor.

The details of traffic on each segment of the Corridor are important to assessment of the relative benefits of improvements for commuter and intercity service. Table 3-3 shows these data.

TABLE 3-3. COMMUTER AND INTERCITY RAIL TRAFFIC AND RIDERSHIP FOR SPECIFIC CORRIDOR SEGMENTS

Segment		Intercity	Commuter	Intercity	Commuter
Between	and	Trains/Day	Trains/Day*	Riders/Yr (M)	Riders/Yr (M)
Harold	New Rochelle	34	0	2.2	0.0
New Rochelle	Stamford	34	185	2.2	22.5
Stamford	Norwalk	34	155	2.1	9.9
Norwalk	Bridgeport	34	78	2.1	6.7
Bridgeport	New Haven	34	60	2.0	2.5
New Haven	Old Saybrook	26	13	1.6	0.2
Old Saybrook	New London	26	0	1.6	0.0
New London	Providence	24	0	1.5	0.0
Providence	Canton	24	57	1.2	1.5
Canton	Route 128	24	151	1.2	4.5
Route 128	Boston	24	151	1.0	5.5

* Revenue-service trains only

Ridership values shown are estimates of passengers carried over the indicated route segment in 1990/91, regardless of origin and destination of riders. Developed from official schedules and other data supplied by Amtrak, MNCR, MBTA, and CDOT. Intercity ridership extrapolated from 1988.

3.3.2 Service Projected for 2010

Intercity Service: Amtrak ridership projections are heavily dependent on the assumptions made concerning service improvements, primarily trip time reductions. One of the more optimistic projections is from a 1989 Amtrak study of the proposals of the Coalition of North East Governors (CONEG) for improved high-speed rail service between Boston and New York. Based on the CONEG assumption of 3-hour trip time, the Amtrak study suggests that total Boston-New York passengers could more than double (from the current 2.2 million to 5 million) and revenues could nearly triple (rising from $76 million to $203 million).

Commuter Services: MNCR and MBTA have each recently projected future ridership levels as part of their planning process. In the case of MNCR, a relatively low rate of growth--about 1% annually--is expected over the next 20 years in westbound peak travel (commuting towards New York City) and a higher annual growth of between 2% and 3% for eastbound ("reverse commuting") and off-peak ridership. These rates are closely related to projected small changes in population, MNCR's current almost-total capture of the market, and employment patterns in the heavily urbanized area from downtown Manhattan to south-central Connecticut served by MNCR.

The resulting projected total increase in weekday riders is about 37% over the next 20 years, increasing from 43,000 weekday riders in 1989 to 52,000 by 2001 and 58,000 in 2011. This increased ridership will be accommodated during the 1990s by a 27% growth in the number of revenue trains from 186 in 1989 to 236 in 2001.

On the northern terminus of the Corridor, the MBTA anticipates a somewhat higher growth in demand. Projected growth in passenger volume along the Corridor from 1990 to 2000 is 41%.

CDOT's new Shore Line East service began within the past year, so there is not enough operational experience to make reasonable projections of future ridership, including the impact of possible extension to New London.

Finally, RIDOT is currently studying commuter rail service from Providence south along the Corridor to Davisville/Quonset Point, a distance of 18 miles. If all RIDOT and CDOT plans are implemented, only the 44-mile stretch of track between New London and Davisville will be without some level of commuter rail operations.

3.3.3 Financial Aspects

Rail passenger transportation services often need subsidies in some form, and those on the Corridor are no exception. Over one-half of the operating costs for Metro-North and two-thirds for MBTA commuter rail service receive public subsidies. Metro-North and MBTA system operating revenues and expenses for 1989 are shown in Table 3-4. Metro-North deficits are funded by MTA and CDOT.

In contrast, Amtrak's financial analysis--based on the concept of the "Long-Term Avoidable Cost" or LTAC associated with each particular route--indicates that service along the Northeast Corridor is one of the few passenger routes on which it operates profitably. Figures for 1989 are given in Table 3-5.

TABLE 3-4. COMMUTER RAIL FINANCIAL OVERVIEW, 1989, IN MILLIONS OF DOLLARS

Operator	Operating Revenues	Operating Expenses	Deficit	Deficit (%)
Metro-North	$ 221 M	$ 402 M	$ 181 M	45%
MBTA	28	79	51	65%
CDOT*	.5	5	4.5	90%

* Shore Line East; service began May 1990.

Other Amtrak routes with this favorable distinction include Metroliner service between New York and Washington, the Autotrain from Virginia to Florida, the New York-Philadelphia-Harrisburg route and the Boston-Newport News route.

TABLE 3-5. OVERVIEW OF AMTRAK NEC FINANCIAL RESULTS, 1989

Route	Revenue ($M)	LTAC ($M)	Revenue/LTAC*	Rev. Pass.-Miles (M)
NEC - Metroliner	$ 110 M	$ 60 M	1.81	305 M
NEC - Conventional	213	155	1.37	1011
Total for All Amtrak Routes	911	999	.91	5840

* A value greater than 1.0 indicates profitability as defined here.

3.4 FREIGHT SERVICE

When Amtrak and state authorities were vested with ownership of the NEC trackage and rights-of-way in the early 1970s, the newly created Conrail received freight operating rights for the Corridor at the prevailing traffic level. As a result of later transfer by Conrail, some of these freight operating rights are now exercised by the Providence and Worcester Railroad (P&W).

Total freight volume along the Northeast Corridor has been decreasing since the major railroad legislation and the start of the NECIP upgrades in the 1970s; the number of daily freight trains on the Corridor declined from 161 in 1977 to only 34 in 1988, of which all but three operated at night. At the present time, total daily freight trains on the north end of the Corridor between New York and Boston number only 15, of which 8 are operated by Conrail and 7 by the P&W.

Conrail now operates only eight regular daily freight trains on the Corridor: three trains between Boston and Attleboro and five trains between Old Saybrook, Connecticut, and Oak Point in the Bronx (about 90 miles). These trains serve only current industrial customers, with no regular through freight trains. Conrail has shifted much of its former Corridor traffic to a route running from Boston westward to the Albany area in New York state.

P&W hauls more than 9,000 carloads of freight annually, representing about one-third of P&W volume, along the Corridor in seven daily trains: one operating on 18 miles of track south from Providence to the port of Davisville/Quonset Point, Rhode Island; two daily trains carrying general freight in the Providence area; and four trains operating over 23 miles of the Corridor in Connecticut between Old Saybrook and Groton. P&W is also negotiating with Conrail for the current Corridor freight operations between Old Saybrook and New Haven, which consists of portions of two routes.

In summary, freight represents a stagnant or declining share of total Corridor operations, with only 15 daily routes scattered along the Corridor. Due to the restrictions imposed both by low overhead bridges and various operating limitations, there appears to be little prospect for major growth in this volume.

3.5 THE FINANCIAL ENVIRONMENT FOR NEC IMPROVEMENTS

3.5.1 State Funding Capacity

All four of the states through which the northern half of the Corridor runs (New York, Connecticut, Rhode Island and Massachusetts) have commuter rail service supported to some extent by the state government and receiving in some cases a significant level of public subsidy, some of which originates with UMTA rather than state revenue sources). However, these states face serious limits in the degree to which they could provide significant financial support for Corridor improvements.

All of these states are currently contending with budgetary deficits of up to 9% of the total budgets for 1991. As of early 1991, the total shortfall for the budgets of all four states was approximately $2.5 billion out of total budgets reaching about $50 billion. In this environment, transportation authorities in these jurisdictions are severely constrained, even in those states with dedicated transportation revenue sources such as gasoline taxes.

For example, the New York MTA's 1992-1996 Capital Program Proposal issued in April 1991, which includes the Long Island and Metro-North Commuter Railroads, projects a capital funding shortfall for the entire MTA system over 5 years in excess of $5 billion, less than $5 billion being available for an identified $10.1 billion in needed projects. This amount is barely sufficient for those projects the MTA judged necessary to maintain current systems in a state of good repair. It does not allow for either the normal replacement of existing items such as rolling stock and track, or for any improvements or expansions of current services.

Connecticut faces a similar situation. A recent study prepared for the Connecticut Department of Transportation, Connecticut Statewide Transit System Plan: Investing in Public Transportation 1990-2010, identified $4.1 billion of capital investments for mass transit within the state over the next 20 years. More than $3 billion of this total is for commuter rail services, with the remainder allocated to bus service and special transit/high occupancy lanes on highways. When operating costs are included, the study projected a total requirement of $11 billion during this period, against anticipated revenues of only $3.9 billion. This shortfall of more than $7.1 billion exists in spite of having a dedicated Special Transportation Fund supported by gas tax and other revenues. (In 1990, $600 million was expended from this fund.) Given the extent of these and other state deficits, states, and their transit authorities will be very limited in their capability to fund significant improvements to the Corridor.

Metro-North Commuter Railroad had operating expenses of $414 million in 1990 against revenues of only $242 million. Of the resulting deficit of $172 million, approximately $64 million was attributable to the New Haven Line. The deficit was met by New York MTA ($132 million, with $24 million toward the New Haven Line) and Connecticut DOT ($40 million, all for the New Haven Line).

The Massachusetts Bay Transportation Authority expended approximately $490 million in 1990. Approximately $82 million of this amount was for commuter rail, one-half involving operations on the Corridor. Revenues covered about 40% of the commuter rail expenditures.

Reauthorization of the Surface Transportation Assistance Act (STAA), currently before the Congress, could substantially affect both the amounts received by states and their flexibility in applying those funds to various transportation needs. Regardless of the form the STAA takes, however, resources available to the states are likely to remain well short of meeting identified needs.

3.5.2 The Private Sector

Major transportation infrastructure projects are often unappealing to private investors. Such projects normally require very large amounts of the funding prior to coming into operation and generating revenue. In the case of such large-scale projects as tunnels, bridges, airports or long-distance roads, this period of time can stretch to a decade or even more. This significant gap between investment and the start of the payback can lead to a minimal or negative return on investment. Only a high degree of confidence in ultimately receiving a substantial stream of revenues can overcome this obstacle.

Another major impediment to private investment in fixed-plant infrastructure projects is that the facility cannot be sold or moved to a more profitable location if the expected return is not realized. For example, if traffic for a toll bridge fails to reach anticipated levels, the investment can become very unprofitable over time, and the structure cannot be diverted to another function.

On the other hand, private investors are traditionally much more willing to invest in the vehicles that use the infrastructure--rail cars and locomotives, ships, aircraft and trucks--because they are mobile and can be easily shifted from less profitable to more profitable routes and uses, or can be sold.

Amtrak has turned to private investors to fund several of their recent major rolling stock purchases, although this approach may have reached the limit that can be supported by current revenue streams. Assessment of its potential for acquiring additional NEC rolling stock is beyond the scope of this study.

For a specific improvement project, electrification, another possibility exists. It is possible that electric utilities would assist in its financing, based, for example, on a later surcharge imposed on Amtrak's billings for electricity. The magnitude and likelihood of this funding mechanism are not known at present.

3.5.3 Amtrak: Nonpassenger Related Revenues

Amtrak's revenues from intercity passenger traffic account for about three-quarters of its total revenue base. The corporation is looking aggressively to other revenue-producing operations to assist in meeting its stated goal of becoming operationally self-sufficient by the year 2000. For example, during FY 1990 the transportation of mail, baggage and express accounted for about $38 million, or about 3%, of Amtrak's total revenues. In the same year the operation of commuter rail services in Massachusetts, Rhode Island, Connecticut, Maryland, the District of Columbia and California brought an additional $165 million in revenues.

Real estate development and operations has recently become another significant nonpassenger revenue source for Amtrak. Prior to FY 1976, the corporation received virtually no revenues attributable to real estate management. By FY 1981 this item generated about $9 million annually, rising to about $24 million by FY 1987 and $40 million in FY 1990. Amtrak expects this amount to more than double by the year 2000.

Amtrak does own several potentially profitable properties on or along the Northeast Corridor. These include:

- 30th Street Station in Philadelphia, with 60 acres of adjacent air rights;
- Pennsylvania Station in New York City, with space leased to both retail shops as well as other commuter rail providers;

- Sunnyside rail yard in Queens, which at 80 acres is one of the largest remaining undeveloped parcels of land in New York City; and

- the track right-of-way itself, on which communications companies such as MCI and AT&T have paid for the right to run long-distance lines.

In addition, the corporation has leased, renovated and/or sold more than one-half of the more than 100 passenger stations it acquired along with the NEC right-of-way.

Similar opportunities, if not as extensive, exist for commuter rail operators along the Corridor. For example, the MBTA is studying the use of air rights at Boston's South Station and property adjacent to the Route 128 passenger stop to generate revenues from real estate development. CDOT owns about 75 acres at the New Haven railroad station complex, including maintenance shops and facilities, and has already participated in joint development projects along the New Haven Line. For example, it contributed $4 million toward a $60 million residential and retail development near South Norwalk station in return for commuter parking spaces.

Although real estate development and revenues from freight and other operations may increase future revenues, the magnitude of such income from locations on the Corridor is unlikely to approach more than a small fraction of the total investment in NEC capital projects needed for major service improvements. For example, Amtrak's total nationwide real estate income is projected at only about $80 million by the year 2000.

3.5.4 Value Capture

Private funding can consist of either of two concepts: first, as investment of private capital, usually as part of a joint public-private venture; and second, as a contribution to the public cost of operating a service through such means as "value capture taxation" or the establishment of "benefit assessment districts." Joint ventures typically consist of the public agency or authority contributing land and/or air rights or real estate, with the private partner investing capital in developing these assets in a way that generates revenue for both parties. As discussed previously, the current real estate climate in the Northeast suggests that this would not be a promising source of large-scale capital in the near term.

The second method is represented by concepts such as that recently proposed to support a High-Speed Rail project in Florida, in which owners of real estate adjacent to the new right-of-way whose property will appreciate in value or whose business incomes will increase because of this proximity would be assessed a fee or tax on this increase. This type of "value capture" has also been proposed in other nations such as the United Kingdom as a means of funding new light rail systems for access to major property developments such as London's "Docklands."

However, this method has met with limited success elsewhere in the U.S. Given the high level of development of the NEC which already exists, and the modest projected near-term economic growth rate in the Northeast, the relevance of this approach to funding of Corridor improvements appears very limited.

3.5.5 <u>The Federal Government</u>

Historically, the Federal government has been a major source of funds for NECIP improvements. As noted previously in Table 3-2, the Federal share of total funds for these NECIP-related projects between New York and Boston was approximately 75%: $1.46 billion of the total $1.94 billion spent between 1970 and 1990. About 54% was NECIP funding via FRA, with the remainder in the form of capital grants from UMTA. If a decision were to be made to provide funds for future Corridor improvements from the Federal government, the most likely mechanisms would be specific direct appropriations channeled through FRA to Amtrak and capital grant funds from UMTA to state governments or transportation agencies.

In addition to these FRA and UMTA funding sources, the Federal Highway Administration (FHWA) manages a "Highway Bridge Replacement and Rehabilitation Program" (HBRRP) with a current annual authorization level of approximately $1.6 billion. As with most such programs, the HBRRP has specific formulas and categories of bridges that can and cannot be included. Funds cannot be used for railroad bridges, but they can be used on road bridges crossing over rail lines. The projects funded by this program have the potential to improve service and trip times along the Northeast Corridor through upgrading substandard or deteriorating road bridges crossing over the Corridor.

Some proposed versions of the Surface Transportation Assistance Act have included funding directed toward high-speed intercity public transportation. While currently directed toward R&D for magnetic levitation, this suggests the possibility that funds for rail corridor improvements could become available from this source. The

Office of Technology Assessment has suggested, for example, that the role of rail passenger service in relieving airport and highway congestion might justify using surface trust fund monies to support Amtrak capital investments in urbanized areas such as that served by the NEC.

4. IMPROVEMENT PROJECTS AND ALTERNATIVE OVERALL PROGRAMS

4.1 INTRODUCTION AND OVERVIEW

This study had three central tasks: (1) identification and characterization of projects to rehabilitate the NEC and improve trip time and service quality for New York-Boston rail passengers; (2) assembly of those projects into a set of alternative overall improvement programs providing successively faster travel; and (3) characterization of each overall program in terms of travel time, cost, logical implementation sequence, and ridership other benefits.

Eighteen projects were identified and used to structure five alternative improvement programs. Technical understanding of the need for each project and the nature of the improvement was based on available documents, supplemented by discussions with involved parties and information requested from appropriate organizations. VNTSC participated with FRA, Amtrak and Metro-North in special examinations of two topics: improvements at the interlocking near New Rochelle, and curve-by-curve assessment of the maximum speed limits potentially feasible along the entire route from New York to Boston. Findings from this process were reviewed by the organizations providing the information.

Based on initial estimates of time savings and cost, the projects were grouped into programs representing a hierarchical succession of trip time reductions and total cost. Trip time was calculated for the speed limit profile appropriate to each of the improvement programs, and repeated for several categories of rolling stock. Existing travel demand models were used to assess the ridership expected to result from the calculated trip times, under reasonable assumptions concerning fare and departure frequency.

Although many of the projects are relatively independent of one another, there are some interrelationships that affect schedule. An approximate logical schedule was developed for each program, with annual program expenditures estimated based on a uniform rate of expenditure over the course of each project.

The results of the project and program characterization process are presented in Section 4. The results of the alternative programs in terms of projected ridership and associated societal benefits are described in Section 5. Remaining uncertainties and necessary circumstances and conditions for actual implementation of any of the improvement programs are discussed in Section 6.

4.2 POTENTIAL IMPROVEMENT PROJECTS

4.2.1 Project Characterization

Projects Identified: The mandate for this study specifically included not only review of previously identified improvements, but also identification of new projects. Given the energies devoted to the Corridor during the last 30 years, one would not expect any totally innovative findings. However, several projects or project elements not emphasized in more-recent NEC studies and proposals were identified. These include a new look at the potential for curve realignment, ballasting of open-deck bridges, and the importance of bridge clearance considerations in electrification. Within the "trackwork" category, many opportunities were found to increase speed by providing greater track superelevation than is now in place. Appendix C provides a review of the various factors which constrain operating speeds.

Table 4-1 lists the 18 identified improvement projects, with an indication of their estimated cost and the manner in which they would improve Corridor service. The table also shows the right-of-way owner at each location. Appendix A contains detailed information concerning each project, presented in a standard format. Table 4-1 and Appendix A are the foundation for the structuring of alternative improvement programs described later in this section. Appendix D describes the detailed analysis conducted to assess the potential costs and trip-time benefits of curve realignments.

As indicated in Table 4-1, the projects identified in this study are of two kinds: (1) Rehabilitation--primarily motivated by safety considerations or needed to bring major elements of the NEC rail infrastructure to a state of good repair (though some of these projects have modest speed benefits or lay a foundation for higher speeds); and (2) System Improvement--contributing to improved scheduled running time and reliability of service. Some are localized (involving a specific bridge, station or interlocking, while others are distributed across part or all of the system (signal system, track improvements). Table 4-2 lists the projects organized by owning agency, with an estimated allocation of distributed improvements among multiple owners.

TABLE 4-1. SUMMARY OF CANDIDATE IMPROVEMENT PROJECT CHARACTERISTICS

CHARACTERISTIC: / PROJECT:	Total Cost ($M, 1991)	Significant Direct Trip Time Impact	Critical to Higher Speed Operation	Critical to Reliability	Critical to Capacity	Safety Impact	Owner
SYSTEM REHABILITATION PROJECTS							
Penn Station/Tunnel	$366 M					X	Amtrak
Catenary Replacement	350	X	X				CDOT
Peck Bridge	86	X				X	CDOT
Movable Bridges	64	X				X	CDOT/Amtrak
Fixed Bridges	213		X				All
SYSTEM IMPROVEMENT PROJECTS							
Harold Interlocking	65			X	X		Amtrak/LIRR
Shell Interlocking	30	X		X	X		MTA
Stamford Island Platforms	30	X		X	X		CDOT
New Haven Terminal	55	X					CDOT/Amtrak
New Haven-Norwalk 4th Track	20				X		MTA
Canton Viaduct	9	X					MBTA
Track Improvements	214		X				All
Signal System Upgrades	13-44		X				All
Grade Crossings	10		X				Amtrak/MBTA
Station Improvements	32	X					MBTA/Amtrak
Electrification	445	X					Amtrak/MBTA
Curve Realignments	715	X					All
New ROW Alignment	1180	X					Amtrak

NOTE: Some projects have already received initial funding by State or Federal agencies. The cost shown in this table is that portion of the total cost in excess of current and past appropriations, expressed in millions of 1991 dollars.

The system improvement projects contribute to improved service in a variety of ways. While some have a direct impact in terms of allowing an increase in authorized train speed, others play a less obvious role. Several projects, including signal systems and fixed bridge improvements, are critical to safety or comfort, and high-speed limits--obtained by straightening curves or other efforts--cannot be used without them. Other projects remove sources of congestion and traffic conflict, or limitations on capacity--either now, or at the expanded traffic levels anticipated for the future.

TABLE 4-2. IMPROVEMENT PROJECTS LISTED BY OWNING ORGANIZATION. DISTRIBUTED PROJECTS SUCH AS MOVABLE BRIDGES AND TRACKWORK ARE DIVIDED AMONG MULTIPLE OWNING AGENCIES. COSTS SHOWN ARE UNFUNDED PORTION, EXPRESSED IN 1991 DOLLARS

OWNER:	Total Cost ($M)	Operators
Amtrak		
Penn Station/Tunnel	$366 M	Amtrak
Hell Gate Catenary Structures	3	Amtrak
Hell Gate Viaduct Rehab./Bridge Conv.	50	Amtrak
Electrification (Conn., RI) (Incl. bridge clearances)	344	Amtrak
Movable Bridges	54	Amtrak
Fixed Bridges (New Haven - Mass. Line)	39	Amtrak
Curve Realignments (New Haven - Mass. Line)	657	Amtrak
New ROW Alignment	1180	Amtrak
Grade Crossings	9	Amtrak
Track Improvements (New Haven - Mass. Line)	20	Amtrak
Track Improvements (Hell Gate)	12	Amtrak
Signal Systems (New Haven - Mass. Line)	115	Amtrak
CDOT		
Peck Bridge	86	MNCR/Amtrak
Catenary Replacement	350	MNCR/Amtrak
Stamford Island Platforms	30	MNCR/Amtrak
New Haven-Norwalk 4th Track	20	MNCR/Amtrak
New Haven Terminal	55	MNCR/Amtrak
Movable Bridges	0	MNCR/Amtrak
Fixed Bridges	105	All
Curve Realignments	51	All
Signal Systems	24	All
MTA		
Shell Interlocking	30	MNCR/Amtrak
Harold Interlocking	65	Amtrak/LIRR
Movable Bridge (Pelham Bay)	10	Amtrak
Fixed Bridges	15	MNCR/Amtrak
Track Improvements	8	MNCR/Amtrak
MBTA		
Electrification (Mass.)	111	Amtrak
Canton Viaduct	9	Amtrak
Grade Crossings	1	Amtrak
Fixed Bridges	15	Amtrak
Track Improvements	33	Amtrak
Curve Realignments	7	Amtrak
Station Improvements (Rt. 128)	7	Amtrak

While some of the rehabilitation projects also have a beneficial impact on travel time, reliability or reduction of congestion, the principal impetus for them is either safety or replacement of fixed plant which has greatly exceeded its service life and now produces operational limitations, high maintenance costs and continuing threats to system reliability.

Although some candidate projects have been studied extensively, and a few have already been initiated, others exist only conceptually, based on little or no detailed analysis or preliminary design. While direct benefits--in terms of higher speed limits or elimination of current impediments to reliable service--can be estimated with confidence, cost poses a more formidable challenge and estimates are necessarily approximate.

Cost Estimation: Projects for which substantive cost estimates were available from prior or concurrent studies were reviewed for completeness and expressed in constant 1991 dollars. For other projects, which included most of those identified, independent estimates were prepared based on a conceptual level of detail. A contingency factor of 30% was applied to the base estimate in each case to arrive at total construction cost. An allowance of 10% for engineering and design, 8% for construction management, and 5% for agency and administrative cost (including flagging protection) was added to arrive at total estimated project cost. In each estimate, the work was broken down into earthwork, structures, trackwork, catenary, signals, and allowance for maintenance of traffic as appropriate. **Most estimates are based on very limited site-specific information and are subject to further detailed investigation and confirmation; however, they are believed to be sufficient to support broad budget formulation.**

All costs are expressed in 1991 dollars; appropriate adjustment for future inflation would be necessary to determine total current-year dollar estimates for any definite construction schedule. This approach thus yields cost estimates which differ from any estimates in other documents that include adjustments for future inflation.

Many of the projects identified have already been allocated initial funding, often for design studies or initial work. **The estimates in Table 4-1 and other tables show only the remaining <u>unfunded</u> portion of the cost**, which is another reason for differences between the table entries and figures shown in other documents. Funded, unfunded, and total cost estimates are shown in the logical sequence charts accompanying the improvement program descriptions presented later in this section, and additional cost-related information is included in the project profiles in Appendix A.

4.2.2 Allocation of Project Benefits

The objectives of this study included assessment of the allocation of benefits among commuters and intercity passengers. In principle, the total passenger-minutes saved by an improvement might be calculated for each category of riders. However, that level of rigor is not possible, since several projects of high relevance to commuters relate to reliability and capacity more than to increased speed limits. Also, as discussed in Section 5, commuters and intercity travelers differ in the economic value placed on their time. Another complication is that improvements related to congestion yield most of their benefits only for those trains operating at peak hours, when congestion is most likely. The less rigorous approach taken in this study is represented by Table 4-3.

Table 4-3 shows, for intercity travelers and commuters, a qualitative estimate of the benefit or importance of each project, and the annual number of riders passing through the location affected by the project. The benefit cannot be made rigorously quantitative, and is simply estimated on a "low-medium-high" scale. Factors which go into this judgement include impacts on speed, capacity, traffic conflicts and operational flexibility, as well as judgements expressed by the involved organizations. The benefits of each project to commuters and intercity passengers are described briefly in Appendix A.

The last column of Table 4-3, Principal Beneficiary, represents a qualitative "multiplication" of the level of benefit by the number of commuters and intercity riders who benefit. In some cases, the result is clear; there are no commuters in that location, or they receive no benefit. For other projects, the conclusion is less certain. These characterizations are for use only to the degree that this highly qualitative approach fits the intended purpose.

4.2.3 Overview of Potential Improvement Projects Along the NEC

Improvement projects are not uniformly distributed along the Corridor. A map indicating some of the major projects is shown in Figure 4-1; trackwork, signaling and curve straightening are too distributed geographically to display in this manner. A brief description of principal projects along specific segments of the Corridor follows.

Hell Gate Line (Penn Station to Shell Interlocking): A major safety-related effort is required at Pennsylvania station. Emergency egress from platforms must be increased, which will be a major undertaking. Similarly, the East River tunnels require new

TABLE 4-3. SUMMARY OF CANDIDATE IMPROVEMENT PROJECT BENEFIT ALLOCATION

PROJECT:	Benefit to Intercity Service	Benefit to Commuter Service	Approx. Number of Intercity Riders Affected (M/Yr)	Approx. Number of Commuters Affected (M/Yr)	Principal Beneficiary (Weighted by Number of Riders)
SYSTEM REHABILITATION PROJECTS					
Penn Station/Tunnel	High	High	2.2	60	Predominantly Commuter
Catenary Replacement	High	High	2.2	25	Predominantly Commuter
Peck Bridge Replacement	Med	Med	2.2	3	Commuter and Intercity
Movable Bridges	Med	Med	2.2	10	Commuter and Intercity
Fixed Bridges	High	Med	1.8 (avg.)	10	Predominantly Intercity
SYSTEM IMPROVEMENT PROJECTS					
Harold Interlocking	Med	Med	2.2	55	Predominantly Commuter
Shell Interlocking	High	Low	2.2	23	Commuter and Intercity
Stamford Island Platforms	High	High	2.2	10	Predominantly Commuter
New Haven Terminal	High	High	2.2	3	Commuter and Intercity
New Haven-Norwalk 4th Track	Med	Low	2.0	5	Predominantly Intercity
Canton Viaduct	High	Med	1.2	3	Commuter and Intercity
Track Improvements	High	Low	1.8 (avg.)	10	Predominantly Intercity
Signal Systems	High	Low	1.0 (avg.)	10	Intercity
Grade Crossings	Low	--	1.5	Varies	Intercity
Station Improvements	Med	Low	1.0	5	Intercity
Electrification (New Haven-Boston)	High	Low	1.6	Varies	Intercity
Curve Realignments	High	Low	1.8 (avg.)	Varies	Intercity
New ROW Alignment	High	--	1.6	N/A	Intercity

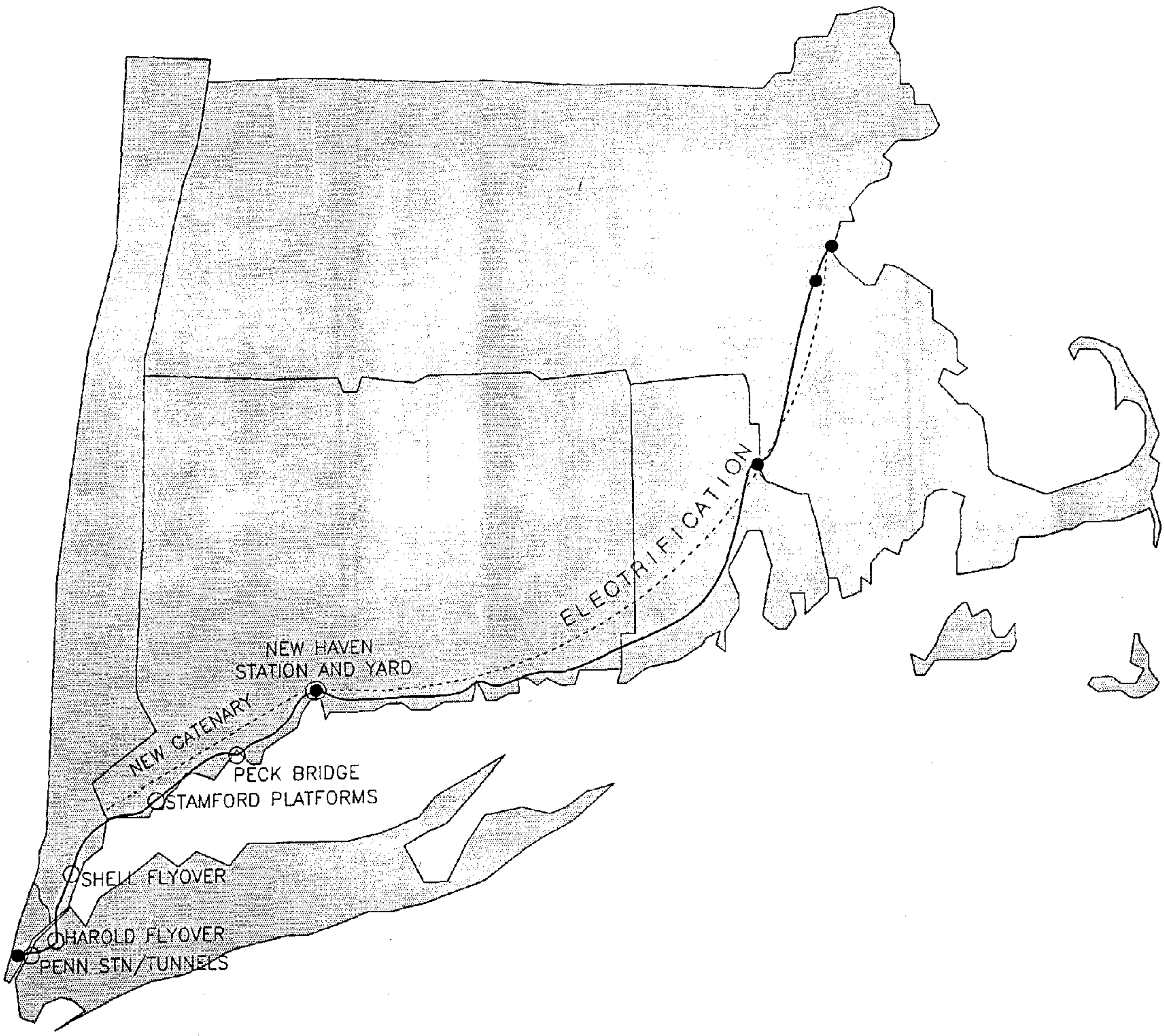


FIGURE 4-1. LOCATION OF SEVERAL MAJOR NEC IMPROVEMENT PROJECTS

ventilation shafts and equipment, including evacuation stairways. At Harold Interlocking, a grade separation (flyover) where eastbound Amtrak trains cross LIRR commuter tracks would prevent delays--likely to be much more serious for the higher Amtrak traffic levels anticipated in the future--but will be difficult to construct while bearing full traffic. Beyond Harold Interlocking on the Hell Gate Line, rehabilitation of the Pelham Bay movable bridge is needed, with other possible improvements including trackwork and a potential curve realignment, and signal modifications for higher speed limits.

New Haven Line (Shell Interlocking to New Haven): The MNCR New Haven Line contains a major share of substantial location-specific projects. Shell Interlocking, where eastbound Amtrak trains merge with MNCR traffic, is a significant source of delay for both railroads, and low-speed turnouts limit operating speeds. Operationally closely linked to Shell, island platforms and related track reconfiguration at Stamford are needed to increase platform access and avoid delays which quickly propagate to New Rochelle. The catenary from the Connecticut-New York line to New Haven is approximately 80 years old and is well beyond normal service life. It now constrains speed limits and imposes an excessive maintenance burden, and replacement is necessary. A project to replace Peck Bridge, a nominally movable bridge over the Pequonnock River at Bridgeport, has been initiated and must be completed; in addition to preventing a future safety problem, this will permit somewhat higher speeds. Four other movable bridges requiring major work are those over the Saugatuck River and Norwalk Rivers and at Cos Cob and Devon. New track configuration at and leading into the New Haven station area would significantly increase speeds and improve operations through that area. All of these specific projects would be accompanied by ballasting of open deck bridges, and trackwork and signaling to permit higher speeds all along the line.

Boston Division (New Haven to South Station): Electrification of this entire route segment would be accompanied by trackwork and signaling to support higher speeds. In addition to conversion of open deck fixed bridges to ballasted deck, electrification would require that overhead bridge clearances be increased at many locations. There is also a potential for significant curve straightening, particularly between New Haven and Providence. Movable bridges at Groton and over the Niantic River require rehabilitation. The viaduct in Canton, Massachusetts, more than 150 years old, needs substantial modification to allow high speed for certain types of commuter cars. High-level platforms at Route 128 station would significantly reduce dwell time at that stop.

4.3 THE PROGRAM DEFINITION AND CHARACTERIZATION PROCESS

4.3.1 Program Definition Process

Conceptually, a set of alternative programs can be defined by ranking improvement projects in order of cost-effectiveness in reducing trip time, with a hierarchy of programs resulting from working down the list. In practice, three considerations limit the rigor with which that approach can be followed: (1) Many of the projects are not well defined at present in scope or design, limiting the precision of both cost and time-savings estimates. This renders highly uncertain any explicit calculation of minutes saved per million dollars expended; (2) Many improvements provide benefits only in conjunction with other projects. For example, the speed gains from simultaneous signal improvements, trackwork, and electrification cannot be allocated uniquely to any one of those projects; and (3) For projects that address trip-time reliability or system capacity, there is no straightforward way to convert the benefit into minutes; they are simply necessary to creating an improved system.

In spite of these limitations, cost-effectiveness in trip time reduction remains a useful measure. Ten projects--or appropriate clusters of projects, like trackwork and signaling--are found to buy reduced trip time (through a combination of higher speeds and prevention of delays) at an approximate rate of $10 million to $20 million per minute saved. The next most attractive improvement, electrification, is found to be somewhat more expensive in direct time savings, but it offers important additional advantages such as efficient Boston-Washington run-through service, fleet rationalization and reduced locomotive maintenance expense. The remaining two projects--curve realignment and a segment of new right-of-way--are significantly more costly (per minute saved) than the other projects identified. Each represents a sufficiently large increment in cost and performance to be embodied in a separate program in the hierarchy. The analysis underlying the curve realignments is presented in Appendix D.

This approach yielded five programs, the first of which consists of the identified rehabilitation projects that are needed for safety and reliability regardless of other benefits, and provide a necessary foundation for concurrent implementation of projects to reduce trip time and improve reliability. In addition, four system-improvement programs were identified. The first consists of the ten most cost-effective nonrehabilitation projects, and the three others are generated by sequentially adding electrification, curve realignments, and the shore line bypass.

No attempt was made to subdivide the first system improvement program further. There is a broad consensus that rail service can begin to compete seriously for the time-sensitive business travel market between New York and Boston only if trip time is approximately 3 hours or less. To achieve a trip time near 3 hours turns out to require, in addition to the five rehabilitation projects, the ten system improvement projects having the highest cost-effectiveness.

The means by which these programs were characterized is described in the following section.

4.3.2 Program Characterization Process

Critical program characteristics are cost, trip time (which depends on the rolling stock used as well as on the improvement program), and ridership. These parameters were estimated as described below.

Cost: Program cost is basically determined by totaling the cost of constituent projects. In some cases, this is program dependent; projects such as signal system or track improvements are necessarily more elaborate and expensive for a program in which other improvements permit higher speeds. The distribution of the many projects over the entire Corridor is such that there are no significant opportunities for cost savings from combined activities, although there is a logical order which must be followed (e.g., track realignments should precede electrification). In some cases project cost varies depending on the program in which it is included; for example, signaling costs are greater in the higher speed Programs 4 and 5 than in 2 and 3.

Trip Time: The most critical element in determining trip time is the profile of allowable speed limits along the entire route. The baseline situation was taken to be that described by the fall, 1990, Amtrak employee timetable. The speed profiles for the hierarchy of performance improvement programs are developed by determining the degree to which each of the various projects which comprise that program will change the allowable speed limits.

As described in Appendix D, these speed limit profiles for each program assume that 6 inches of superelevation are used wherever the transition distance (spiral) appears adequate and other factors do not constrain the situation. It is further assumed that 6 inches of unbalance will prove acceptable to Amtrak and FRA, based on future tests and analysis. The use of these higher speeds would require extensive improvements to track structures, as will be described below.

The assumption of 6-inch unbalance and 6-inch superelevation represents a "best case" scenario, which might not be fully realizable. This approach is used to define the shortest trip time which might reasonably be sought during the next ten years for various levels of investment. Extensive testing and analysis would ultimately be required to establish the degree, if any, to which this target need be revised. This assumption does not imply that higher speeds should or can be used at the present time.

Running time for a specified speed profile with a particular train is calculated using the US DOT Train Performance Simulator, a train performance calculator (TPC) computer program which has been used for this purpose in several previous studies; it is also used by Amtrak and Metro-North. The TPC seeks to run the simulated train at the maximum speed, within the constraint of available acceleration, train braking characteristics, and wheel-rail adhesion. Acceleration is not allowed until the last car of the train has left the previous speed zone, and the program "looks ahead" to decelerate in advance of speed restrictions. Computer outputs include a schedule of the train along the route and information as to the percentage of time spent in each speed range (using 10-MPH increments). The TPC is described in greater detail in Appendix B.

The computer calculations are inherently idealized--all station dwell times occur as specified, the train always seeks the maximum allowed speed, and there are no delays or traffic conflicts. In railroad terminology, the schedule produced has zero "pad." Modifications based on professional judgement and experience are necessary to generate a realistic train schedule from the predictions of the Train Performance Calculator.

The primary modification to TPC results applied in this study is to increase the raw computed run times by 5%. This adjustment is consistent with passenger railroad practices when estimating potential trip times, and yields the actual scheduled running time (3:55) when applied to a TPC simulation of the *New England Express*. Since it is quite possible that in some cases inadequate transition distance or other factors will prevent full attainment of the curve speed limits, additional adjustments are made to the TPC calculations prior to the 5% increase. One minute is added to all computed trip times for Programs 2 and 3. Computed trip time for Programs 4 and 5, which incorporate the curve realignments, is increased by 2 minutes. Since tilt suspensions depend to a greater degree on still higher curve speeds and longer transitions, the TPC time is increased by an additional minute for all tilt trains runs.

For schedules determined in this manner to be attained in practice, the entire system would have to be operated with the highest level of precision and efficiency. All operations--intercity, commuter, and maintenance--would require rigorous schedule adherence, with equipment and fixed plant meeting very high reliability standards. Scheduling would have to be based on a realistic understanding of system capacity, including allowance for inevitable variations.

The trip times estimated in this study are the best which might be achieved for each set of improvements. Reliable attainment of those values would require full validity of all assumptions, as well as passenger operations which meet the highest standards of precision and reliability in all respects. Practical scheduled running times could be several minutes greater than the values presented in this report. It should be noted, however, that if a more conservative view were taken, perhaps by adding an additional 5 or so minutes of pad, the <u>differences</u> between trip times for various programs and rolling stock choices would be little changed.

Operational Scenarios: For the travel time comparisons in this study, four intermediate stops were assumed on a Boston (South Station)-New York (Pennsylvania Station) run: Back Bay, Route 128, Providence and New Haven. This is the pattern currently used for the fastest Amtrak train on this route, the *New England Express*. Dwell time of 75 seconds is assumed, except for a 10-minute engine-change stop in New Haven for the "Current" rolling stock option. An additional stop at Stamford, usually included in Amtrak descriptions of future high-speed service, would add approximately 3 minutes. Calculations are made for a six-car train, which is consistent with Amtrak plans; an additional car would have small impact on running times.

Although the focus in this analysis is on minimum-trip-time express service, it is expected that any actual operating plan would be patterned after the current service between New York and Washington, which includes both Metroliner and conventional service. Indeed, Amtrak generally describes future NEC services as based on both Metroliner and conventional trains (eight or more stops north of New York and eight to twelve cars) running from Boston to Washington, each class of service generally having hourly departures. The ridership associated with the conventional service is likely to be a substantial fraction of total patronage. Trip times for several varieties of conventional service are shown later in this section.

Rolling Stock: For the purpose of trip time calculations, the rolling stock choices need not be specified in great detail. The principal determinants of trip duration are locomotive horsepower and train weight, which determine both maximum speed attainable and acceleration. Standard values for passenger equipment are used for the equation which expresses the train's resistance to motion in terms of its velocity, weight, and other specifications. The simulation does not necessarily duplicate the physical characteristics of current locomotives, coaches and trainsets, particularly with regard to lightweight electric trains for which several variations exist. However, each rolling stock scenario is based on a close match to equipment now in revenue service.

Four motive power alternatives were used in calculating trip time for each program:

- "Current": Two 130-ton 3000 HP diesel-electric locomotives from Boston to New Haven; one 100-ton 7000 HP electric locomotive from New Haven to Pennsylvania Station. (Comparable to current F40P and AEM-7 locomotives; a 10-minute dwell is assumed for the New Haven station stop and engine change.)

- "Electric": One 100-ton 7000 HP electric locomotive from New Haven to Penn Station for Programs 1 and 2, Boston to New York for Programs 3 through 5. (Comparable to current Amtrak AEM-7 locomotive.)

- "High-Speed Electric": Two 75-ton 7000 HP electric power units, operating as part of a lightweight trainset. (Roughly comparable to current advanced foreign rail equipment such as the French TGV, Swedish X2000, and German ICE.)

- "Turbo": Two 80-ton gas turbine power units having a total of 2280 HP, with third-rail capability for operation in the East River Tunnels. (Comparable to gas turbine units now used on Amtrak's Empire Service between New York City and Albany.)

Six 58-ton cars (comparable to current Amcoaches) are assumed for the Current and Electric cases; the High-Speed Electric and Turbo cases assume cars 20% lighter as a lower bound on the weight likely to be achievable. The Electric case, which is basically conventional, and the High-Speed Electric case, representative of available advanced technology, define performance boundaries for electrified equipment likely in the foreseeable future. A turbine train making use of twin turbines of newer design on each power car, with a total power of 5800 HP, has been proposed, but does not currently exist.

The predicted performance of tilt-suspension rolling stock is computed not by changing the parameters describing the train, but rather by modifying the track speed limit profile on the assumption that a tilt train would be able to operate at 8 inches of unbalance on any curve that is operable at 6 inches by conventional equipment. This assumption is consistent with the general findings of tests run on the Corridor in 1988, which suggested that passenger comfort on tilting coaches at 8 inches unbalance was approximately equal to that on conventional equipment at 6 inches. This assumption, which is critical to estimating the potential speed impact of tilt trains, remains to be validated and accepted by the FRA. It is also necessary that the locomotive be both safe and comfortable for the crew when operating at the 8-inch unbalance speeds. In addition, assurance of adequate transition distance between curves and tangent track is particularly critical with regard to this high-unbalance option.

Logical Program Sequence and Expenditure Schedule: For each improvement program, a broad overall schedule was developed based <u>only</u> on logical sequencing of projects. These schedules suggest a practical minimum length of time for the implementation period. They are based on the assumption that funding is not a constraint, and that environmental and other requirements can be met without excessive delay; the reality could be substantially different.

Each schedule includes an indication of the construction expenditures, in 1991 dollars, for each year, assuming project cost to be uniformly distributed over the implementation period. If these figures are used for budgetary purposes, they must be adjusted for assumed inflation values and lead times associated with the appropriation and obligation process. The schedules also show explicitly for each project the total estimated cost, the amount already available (appropriated and allocated), and the portion remaining unfunded.

Ridership and Program Benefits: The increases in ridership to be expected from faster travel are estimated on the basis of analytical models developed and refined in recent years for that purpose in various corridors around the U.S. and abroad. The model used estimates not only the total ridership, but also the portion of new riders who otherwise would have traveled by air and private automobile. Section 5 of this report provides a detailed discussion of projected ridership and other benefits and the means by which they are estimated.

4.4 ALTERNATIVE NEC IMPROVEMENT PROGRAMS

4.4.1 Program 1. System Rehabilitation

The System Rehabilitation program consists only of projects required for safety, replacement or rehabilitation of major system elements which have substantially exceeded normal service life, and major improvements necessary to bring the system infrastructure to a state of good repair. This program includes replacement of Peck Bridge, ventilation and other improvements to Penn Station and the East River Tunnels, and replacement of catenary between the New York-Connecticut line and New Haven. It also encompasses rehabilitation or replacement of other movable and fixed bridges.

Most of these projects involve fixed plant originally constructed near the beginning of this century. The Penn Station and Tunnel work and replacement of Peck Bridge are based on specific safety needs identified in previous studies. The existing catenary requires excessive continuing maintenance expense, necessitates speed restrictions and reduces service reliability, and precludes raising of operating speeds. As can be seen in Table 4-3, this program has its greatest benefits for commuter services, but will also be very important for intercity operations.

Table 4-4 shows program cost, trip time and ridership for each relevant rolling stock option. Since New Haven-Boston electrification is not part of this program, only Current and Turbo rolling stock options are possible. A logical project sequence and funding schedule is shown in Figure 4-2.

TABLE 4-4. TRIP TIME AND PROJECTED RIDERSHIP FOR PROGRAM 1

PROGRAM 1: SYSTEM REHABILITATION		EST. TOTAL COST: $1.1 B
ROLLING STOCK	**TRIP TIME (HRS:MIN)**	**ANNUAL RIDERSHIP (M)**
Current (Diesel-Electric + Electric)	3:47	4.04
Current/Tilt Suspension	3:46	4.05
Turbo	3:48	4.02

Assumes hourly operation of conventional and express service.
Current fastest schedule: 3:55; current annual ridership 2.3 million.

The trip time for the "Current" rolling stock option is 8 minutes less than the schedule time of the *New England Express*. The basic reasons for this difference are that a six-car train is assumed, (rather than the four cars on the *Express*), and they are pulled by two diesel locomotives from Boston to New Haven, rather than one.

	PROJECT *	ESTIMATED COST (1991 $ MILLIONS) UNFUNDED	FUNDED	TOTAL
1	N.Y. PENN STATION AND TUNNEL IMPROVEMENTS	366	9	375
2A	CATENARY REPLACEMENT (STATE LINE - NEW HAVEN)	347	0	347
2B	CATENARY REPLACEMENT (SHELL - STATE LINE)	0	24	24
2C	CATENARY STRUCTURE REHABILITATION (HELL GATE)	3	0	3
3	PECK BRIDGE REPLACEMENT	86	23	109
4A	MOVABLE BRIDGE - THAMES RIVER, MOVABLE SPAN	33	0	33
4B	MOVABLE BRIDGE - NIANTIC RIVER, ENTIRE BRIDGE REPLACEMENT	21	0	21
4C	MOVABLE BRIDGE - SAGA BRIDGE, REHABILITATION	0	9	9
4D	MOVABLE BRIDGE - COS COB BRIDGE, REHABILITATION	0	20	20
4E	MOVABLE BRIDGE - WALK BRIDGE, REHABILITATION	0	13	13
4F	MOVABLE BRIDGE - DEVON BRIDGE, REHABILITATION	0	17	17
4G	MOVABLE BRIDGE - PELHAM BAY BRIDGE, REHABILITATION	10	0	10
5A	FIXED BRIDGES - AMTRAK, NEW HAVEN-BOSTON CONVERSION TO BALLASTED DECK	43	5	48
5B	FIXED BRIDGES - METRO NORTH CONVERSION TO BALLASTED DECK	120	0	120
5C	FIXED BRIDGES - AMTRAK HELL GATE, VIADUCT REHABILITATION AND BRIDGE CONVERSIONS	50	0	50
	TOTALS	1,079	120	1,199

YEARLY EXPENDITURE † (1991 $ MILLIONS)	IN PROGRESS	1	2	3	4	5	6	7	8	9	10
	120	55	105	200	194	183	162	151	29		

LEGEND

- ------ ENVIRONMENTAL PROCESS, R.O.W. ACQUISITION AND DESIGN
- ——— CONSTRUCTION
- * PROJECT DETAILS ARE CONTAINED IN APPENDIX A
- † YEARLY EXPENDITURES ARE BASED SOLELY ON SEQUENCING CONSIDERATIONS AND NOT ON FUNDING AVAILABILITY

PROGRAM 1 - SYSTEM REHABILITATION

FIGURE 4-2. PROJECT COST ESTIMATES AND LOGICAL SEQUENCING FOR PROGRAM 1, SYSTEM REHABILITATION

The speed limit profile assumed is based on the fall, 1990, Amtrak employee schedule, but with special restrictions removed. Curve speed limits are computed based on existing superelevation but assuming 6-inch unbalance to be permissible. The maximum speed allowed on straight track is 110 MPH. Program 1 does not include any projects directly aimed at higher speed, but speed limits at some locations, such as at Peck Bridge, would be increased. For the case of turbine power with third-rail capability, the 10-minute engine change at New Haven is eliminated, but the existing turbine train is constrained by a low power-to-weight ratio. A version making use of twin turbines of newer design on each power car, with a total power of 5800 HP, has been proposed. If this equipment were successfully developed and tested, trip time with turbine power would be improved by about 25 minutes compared to the value in Table 4-5. However, there are additional obstacles to use of turbine power, as noted in Section 6.

4.4.2 Program 2: Basic System Improvements

The Basic System Improvement Program includes all of the rehabilitation projects in Program 1 and adds ten projects, to be performed concurrently with the rehabilitation work, to increase speed limits, reduce delays and improve reliability. Approximately 33 minutes will be gained by trackwork and signaling to increase running speeds to a maximum of 130 MPH, particularly between Boston and New Haven. Superelevation is raised to 6 inches everywhere possible. Modernization of the New Haven terminal area will eliminate an extended region of very slow speeds, cutting an additional 5 minutes from the trip while significantly increasing operational flexibility and efficiency and reducing maintenance expenses. Interrelated improvements at Shell Interlocking and Stamford station will increase speed limits at those locations significantly, and will yield even more significant benefits by reducing congestion and traffic conflicts.

Installation of high-level platforms at Route 128 Station will reduce dwell time. Distributed improvements include signal system upgrades, conversion of open deck bridges to ballasted decks, grade crossing improvements, and installation of concrete ties. A grade separation at Harold Interlocking and replacement of the fourth track from New Haven to Norwalk are not critically needed at present, but will be necessary to avoid congestion and conflict from increased traffic, probably within 10 years. The average speed attained for this program is about 75 MPH.

Table 4-5 shows cost, trip time and estimated ridership for each relevant rolling stock option. Since New Haven-Boston electrification is not included in this program, the only rolling stock options possible are Current and Turbo. A logical project sequence and funding schedule is shown in Figure 4-3.

TABLE 4-5. TRIP TIME AND PROJECTED RIDERSHIP FOR PROGRAM 2

PROGRAM 2: BASIC SYSTEM IMPROVEMENTS		EST. TOTAL COST: $1.6 B
ROLLING STOCK	**TRIP TIME (HRS:MIN)**	**ANNUAL RIDERSHIP (M)**
Current (Diesel-Electric + Electric)	3:07	4.63
Current/Tilt Suspension	3:02	4.77
Turbo	3:21	4.42

Current fastest schedule: 3:55; current annual ridership 2.3 million.

4.4.3 Program 3: Basic System Improvements and Electrification

Program 3 supplements the projects of Program 2 by electrifying the route between New Haven and Boston. Electrification eliminates the engine change in New Haven, a saving of over 9 minutes, and allows use of electric locomotives for the Boston-New Haven segment. Their higher acceleration and top speed reduce the trip time by about 6 minutes. Electrification also facilitates run-through operation between Boston and Washington, significantly improving Pennsylvania Station and East River Tunnel capacity and providing high-speed service for travellers between Boston or Providence and points south of New York. Maximum authorized speed is 130 MPH; average speeds, depending on rolling stock, are above 80 MPH.

Table 4-6 shows program cost, trip time and estimated ridership for each rolling stock option. It is unlikely that electrification would be undertaken if diesel or turbine power were to be used, so trip times are shown only for Electric and High-Speed Electric. (Turbine and diesel times would be the same as in Table 4-5.) A logical project sequence and funding schedule is shown in Figure 4-4.

4.4.4 Program 4: All System Improvements and Electrification

Program 4 includes all projects in Program 3, plus realignments of 27 curves (in five groups), in some cases requiring a small excursion from the current right-of-way. Maximum speed is 130 MPH. These improvements provide a further reduction in trip time of about 11 minutes, almost all achieved east of New Haven. The resulting average speed is approximately 90 MPH.

	PROJECT *	ESTIMATED COST (1991 $ MILLIONS) UNFUNDED	FUNDED	TOTAL
1	N.Y. PENN STATION AND TUNNEL IMPROVEMENTS	366	9	375
2	CATENARY REPLACEMENT AND STR. REHABILITATION	350	24	374
3	PECK BRIDGE REPLACEMENT	86	23	109
4	MOVABLE BRIDGES	64	59	123
5	FIXED BRIDGES	213	5	218
6	HAROLD INTERLOCKING - (EASTBOUND FLYOVER)	65	0	65
7	SHELL INTERLOCKING - IMPROVEMENT	30	25	55
8	STAMFORD STATION - ISLAND PLATFORMS	30	0	30
9	NEW HAVEN STATION - YARD/APPROACH	55	5	60
10	NEW HAVEN - NORWALK, 4th TRACK	20	0	20
11	CANTON VIADUCT	9	1	10
12	TRACK IMPROVEMENTS (FULL SUPERELEVATION, FIT CURVES, ADDED TRACK, HIGH SPEED CROSSOVERS, CONCRETE TIE REPLACEMENT)	214	6	220
13	SIGNAL SYSTEM UPGRADES	14	56	70
14	GRADE CROSSING IMPROVEMENTS	10	0	10
15	STATIONS	32	1	33
	TOTALS	1,558	214	1,772

YEARLY EXPENDITURE † (1991 $ MILLIONS)	IN PROGRESS	1	2	3	4	5	6	7	8	9	10
	214	118	183	237	244	248	227	216	78	6	6

LEGEND

- - - - - ENVIRONMENTAL PROCESS, R.O.W. ACQUISITION AND DESIGN

——— CONSTRUCTION

* PROJECT DETAILS ARE CONTAINED IN APPENDIX A

† YEARLY EXPENDITURES ARE BASED SOLELY ON SEQUENCING CONSIDERATIONS AND NOT ON FUNDING AVAILABILITY

PROGRAM 2 - BASIC SYSTEM IMPROVEMENTS

FIGURE 4-3. PROJECT COST ESTIMATES AND LOGICAL SEQUENCING FOR PROGRAM 2, BASIC SYSTEM IMPROVEMENTS

TABLE 4-6. TRIP TIME AND PROJECTED RIDERSHIP FOR PROGRAM 3

PROGRAM 3: BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION		EST. COST: $2.0 B
ROLLING STOCK	**TRIP TIME (HRS:MIN)**	**ANNUAL RIDERSHIP (M)**
Electric/Tilt Suspension	2:52	4.91
Electric/Tilt Suspension	2:47	5.04
High-Speed Electric	2:46	5.07
High-Speed Electric/Tilt Suspension	2:41	5.18

Current fastest schedule: 3:55; current annual ridership 2.3 million.

Table 4-7 shows program cost, trip time and estimated ridership for each rolling stock option. As for Program 3, trip times are shown only for Electric and High-Speed Electric propulsion. A logical project sequence and funding schedule is shown in Figure 4-5.

TABLE 4-7. TRIP TIME AND PROJECTED RIDERSHIP FOR PROGRAM 4

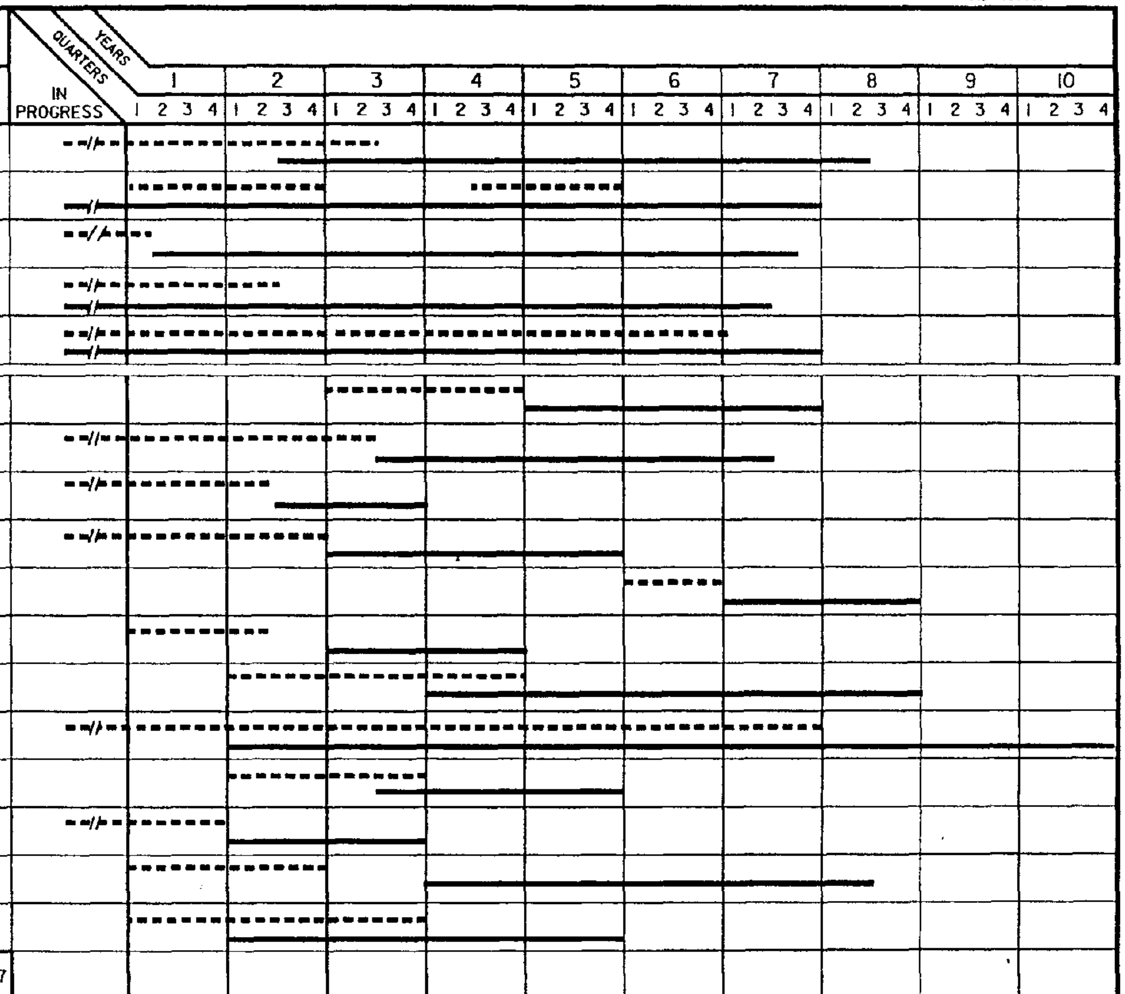
PROGRAM 4: ALL SPEED IMPROVEMENTS AND ELECTRIFICATION		EST. COST: $2.7 B
ROLLING STOCK	**TRIP TIME (HRS:MIN)**	**ANNUAL RIDERSHIP (M)**
Electric/Tilt Suspension	2:41	5.22
Electric/Tilt Suspension	2:37	5.32
High-Speed Electric	2:35	5.34
High-Speed Electric/Tilt Suspension	2:33	5.43

Current fastest schedule: 3:55; current annual ridership 2.3 million.

4.4.5 Program 5: Shore Line Bypass

Program 5 adds to Program 4 a new routing to avoid the most curve-intensive portion of the route. The Shore Line Bypass, recently examined by Amtrak, is a 50-mile long 150-MPH right-of-way bypassing the most curved section of the route along the Connecticut and Rhode Island shore east of New Haven. This reduces trip time by about 11 minutes and yields an average speed of approximately 95 MPH. The $850 million cost increase compared to Program 4 takes into account deductions for expenditures in Programs 2 through 4--for some of the curve realignments and bridge rehabilitations--which would not be needed if a bypass were constructed.

	PROJECT *	ESTIMATED COST (1991$ MILLIONS) UNFUNDED	FUNDED	TOTAL
1	N.Y. PENN STATION AND TUNNEL IMPROVEMENTS	366	9	375
2	CATENARY REPLACEMENT AND STR. REHABILITATION	350	24	374
3	PECK BRIDGE REPLACEMENT	86	23	109
4	MOVABLE BRIDGES	64	59	123
5	FIXED BRIDGES	213	5	218
6	HAROLD INTERLOCKING (EASTBOUND FLYOVER)	65	0	65
7	SHELL INTERLOCKING IMPROVEMENT	30	25	55
8	STAMFORD STATION - ISLAND PLATFORMS	30	0	30
9	NEW HAVEN STATION - YARD/APPROACH	55	5	60
10	NEW HAVEN - NORWALK, 4th TRACK	20	0	20
11	CANTON VIADUCT	9	1	10
12	TRACK IMPROVEMENTS	214	6	220
13	SIGNAL SYSTEM UPGRADES	39	56	95
14	GRADE CROSSING IMPROVEMENTS	10	0	10
15	STATIONS	32	1	33
16A	NEW HAVEN - BOSTON ELECTRIFICATION	345	25	370
16B	VERTICAL CLEARANCE ATTAINMENT	100	0	100
	TOTALS	2,028	239	2,267



YEARLY EXPENDITURE † (1991$ MILLIONS)	IN PROGRESS	1	2	3	4	5	6	7	8	9	10
	239	127	213	269	346	349	306	291	118	5	4

LEGEND

- ▬ ▬ ▬ ENVIRONMENTAL PROCESS, R.O.W. ACQUISITION AND DESIGN
- ▬▬▬ CONSTRUCTION
- * PROJECT DETAILS ARE CONTAINED IN APPENDIX A
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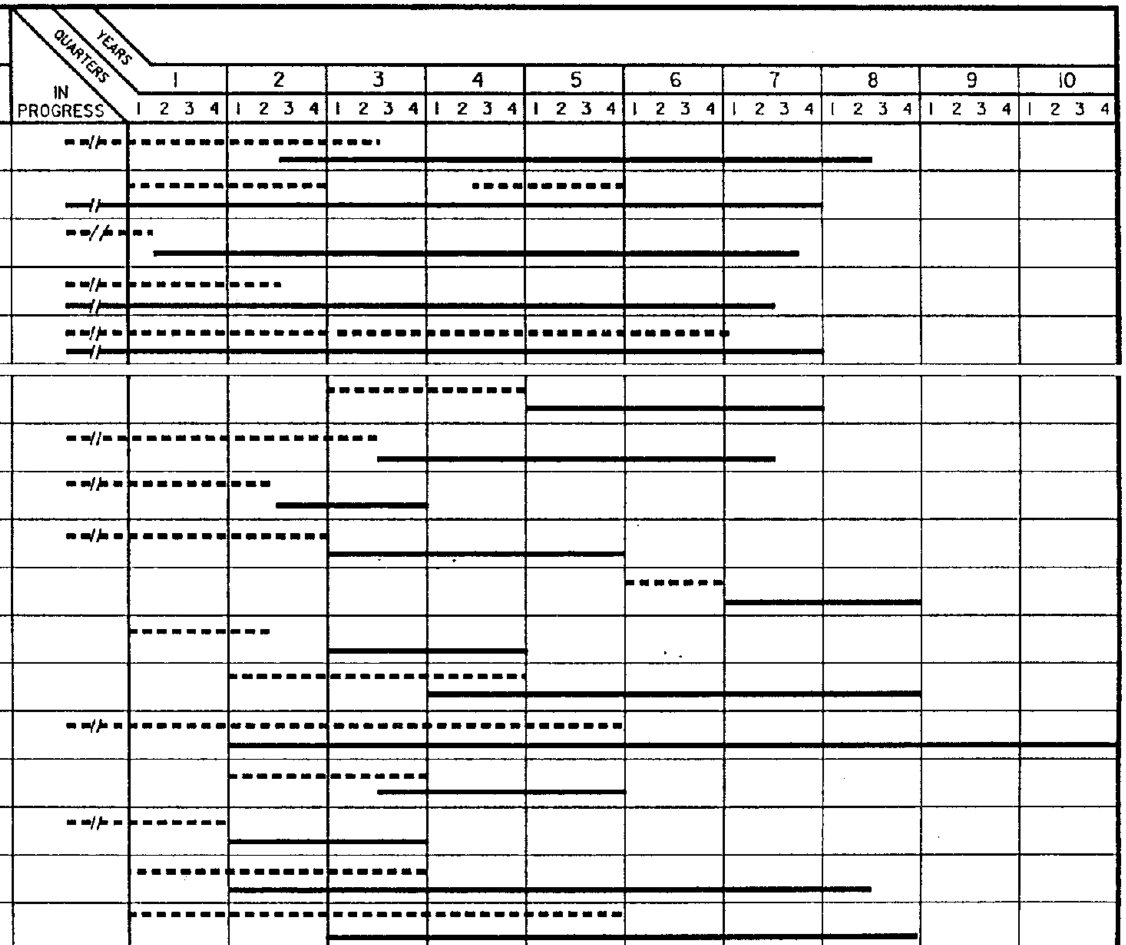
PROGRAM 3 - BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION

FIGURE 4-4. PROJECT COST ESTIMATES AND LOGICAL SEQUENCING FOR PROGRAM 3, BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION

	PROJECT *	ESTIMATED COST (1991 $ MILLIONS) UNFUNDED	FUNDED	TOTAL
1	N.Y. PENN STATION AND TUNNEL IMPROVEMENTS	366	9	375
2	CATENARY REPLACEMENT AND STR. REHABILITATION	350	24	374
3	PECK BRIDGE REPLACEMENT	86	23	109
4	MOVABLE BRIDGES	64	59	123
5	FIXED BRIDGES	213	5	218
6	HAROLD INTERLOCKING (EASTBOUND FLYOVER)	65	0	65
7	SHELL INTERLOCKING IMPROVEMENT	30	25	55
8	STAMFORD STATION - ISLAND PLATFORMS	30	0	30
9	NEW HAVEN STATION - YARD/APPROACH	55	5	60
10	NEW HAVEN - NORWALK, 4th TRACK	20	0	20
11	CANTON VIADUCT	9	1	10
12	TRACK IMPROVEMENTS	214	6	220
13	SIGNAL SYSTEM UPGRADES	44	56	100
14	GRADE CROSSING IMPROVEMENTS	10	0	10
15	STATIONS	32	1	33
16	NEW HAVEN - BOSTON ELECTRIFICATION	445	25	470
17	CURVE REALIGNMENTS	715	0	715
	TOTALS	2,748	239	2,987



YEARLY EXPENDITURE † (1991 $ MILLIONS)	IN PROGRESS	1	2	3	4	5	6	7	8	9	10
	239	140	271	433	435	439	405	389	220	8	[illegible]

LEGEND

- ▪▪▪▪▪ ENVIRONMENTAL PROCESS, R.O.W. ACQUISITION AND DESIGN
- ▬▬ CONSTRUCTION
- * PROJECT DETAILS ARE CONTAINED IN APPENDIX A
- † YEARLY EXPENDITURES ARE BASED SOLELY ON SEQUENCING CONSIDERATIONS AND NOT ON FUNDING AVAILABILITY

PROGRAM 4 - ALL SYSTEM IMPROVEMENTS AND ELECTRIFICATION

FIGURE 4-5. PROJECT COST ESTIMATES AND LOGICAL SEQUENCING FOR PROGRAM 4, ALL SYSTEM IMPROVEMENTS AND ELECTRIFICATION

Constructing a bypass would be a lengthy and complex undertaking. Uncertainties of land acquisition and environmental impacts create a substantially higher risk of delay and cost escalation than would be expected for the set of curve realignments in Program 4, which has approximately the same nominal cost-effectiveness.

Table 4-8 shows trip time for each rolling stock option and estimated ridership. As for Program 3, trip times are shown only for Electric and High-Speed Electric propulsion. The single locomotive used in the Electric case actually only reaches 137 MPH; about 5 minutes could be saved by a second locomotive. A logical project sequence and funding schedule is shown in Figure 4-6.

TABLE 4-8.. TRIP TIME AND PROJECTED RIDERSHIP FOR PROGRAM 5

PROGRAM 5: SHORE LINE BYPASS		**EST. COST: $3.6 B**
ROLLING STOCK	**TRIP TIME (HRS:MIN)**	**ANNUAL RIDERSHIP (M)**
Electric	2:29	5.51
Electric/Tilt Suspension	2:28	5.58
High-Speed Electric	2:22	5.70
High-Speed Electric/Tilt Suspension	2:21	5.78

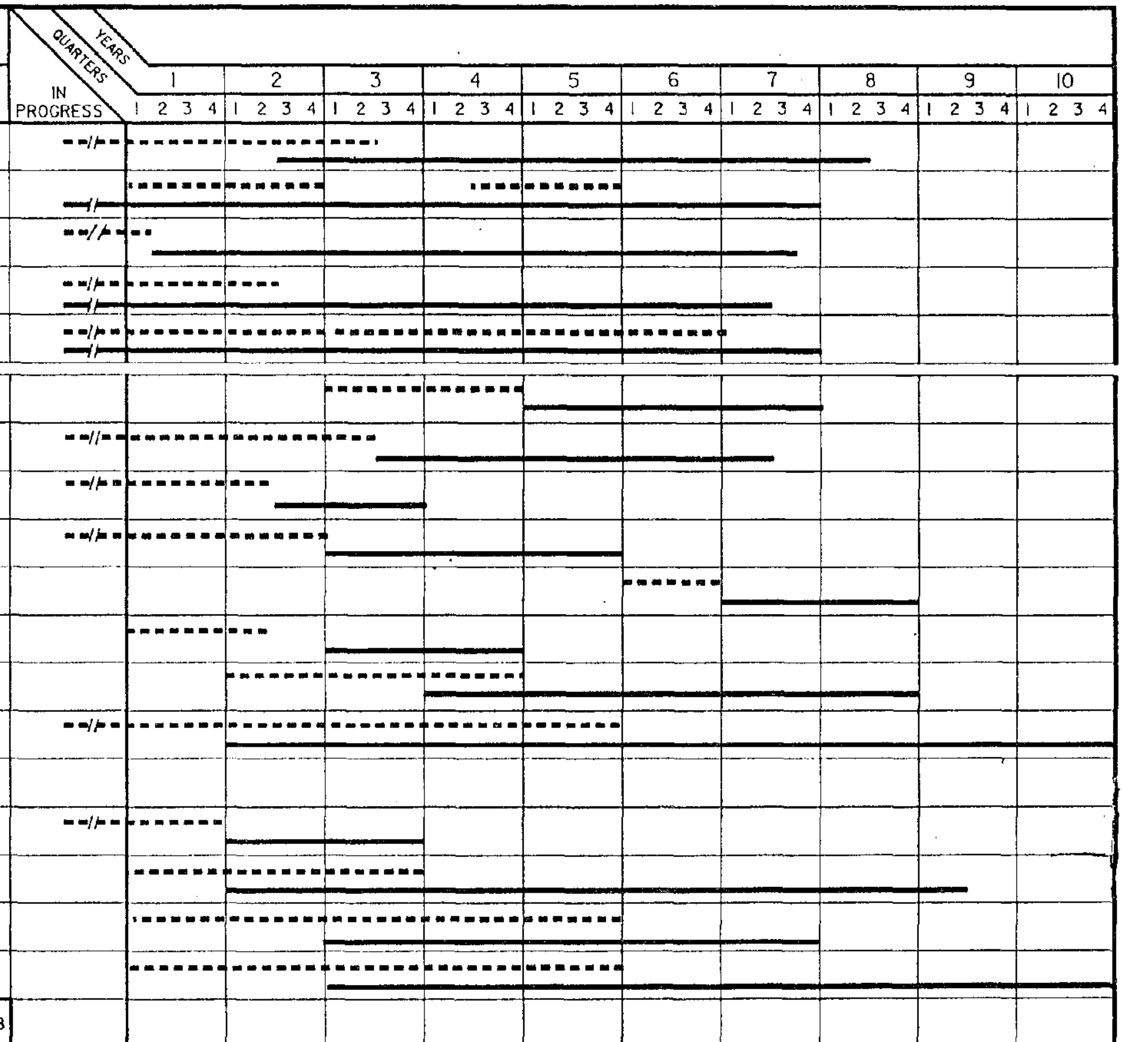
Current fastest schedule: 3:55; current annual ridership 2.3 million.

4.5 SUMMARY AND COMPARISON OF ALTERNATIVE PROGRAMS

4.5.1 Summary of Projects

Table 4-9 shows the projects included in each alternative program. **It is emphasized that this hierarchy of programs, in which successive programs are created by inclusion of additional projects, does not imply that it would be feasible to implement any one program and then "upgrade" to more extensive improvements of another program by simply adding the omitted projects.** It is essential that design of individual projects be based on specification of the overall system of which they will be a part--whether it is electrified, maximum planned speed limits, etc. Even more important is the need to assure that the sequencing of projects and details of the staging of each project be coordinated to minimize the inevitable disruption to service while construction is in progress.

	PROJECT *	ESTIMATED COST (1991 $ MILLIONS) UNFUNDED	FUNDED	TOTAL
1	N.Y. PENN STATION AND TUNNEL IMPROVEMENTS	366	9	375
2	CATENARY REPLACEMENT AND STR. REHABILITATION	350	24	374
3	PECK BRIDGE REPLACEMENT	86	23	109
4	MOVABLE BRIDGES	10	59	69
5	FIXED BRIDGES	213	5	218
6	HAROLD INTERLOCKING (EASTBOUND FLYOVER)	65	0	65
7	SHELL INTERLOCKING IMPROVEMENT	30	25	55
8	STAMFORD STATION - ISLAND PLATFORMS	30	0	30
9	NEW HAVEN STATION - YARD/APPROACH	55	5	60
10	NEW HAVEN - NORWALK, 4th TRACK	20	0	20
11	CANTON VIADUCT	9	1	10
12	TRACK IMPROVEMENTS	214	6	220
13	SIGNAL SYSTEM UPGRADES	44	56	100
14	GRADE CROSSING IMPROVEMENTS (BYPASSED)	0	0	0
15	STATIONS	32	1	33
16	NEW HAVEN - BOSTON ELECTRIFICATION	445	25	470
17	CURVE REALIGNMENTS EXCEPT BYPASS ALIGNMENT (OLD SAYBROOK - BRADFORD)	450	0	450
18	BYPASS ALIGNMENT (OLD SAYBROOK - BRADFORD)	1,180	0	1,180
	TOTALS	3,599	239	3,838



YEARLY EXPENDITURE † (1991 $ MILLIONS)	IN PROGRESS	1	2	3	4	5	6	7	8	9	10
	239	152	281	567	566	560	509	488	252	146	78

LEGEND

- - - - - ENVIRONMENTAL PROCESS, R.O.W. ACQUISITION AND DESIGN
——— CONSTRUCTION

* PROJECT DETAILS ARE CONTAINED IN APPENDIX A
† YEARLY EXPENDITURES ARE BASED SOLELY ON SEQUENCING CONSIDERATIONS AND NOT ON FUNDING AVAILABILITY

PROGRAM 5 - SHORE LINE BYPASS

FIGURE 4-6. PROJECT COST ESTIMATES AND LOGICAL SEQUENCING FOR PROGRAM 5, SHORE LINE BYPASS

TABLE 4-9. COST OF PROJECTS COMPRISING ALTERNATIVE IMPROVEMENT PROGRAMS IN MILLIONS OF 1991 DOLLARS

PROGRAM:	1. SYSTEM REHABILITATION	2. BASIC SYSTEM IMPROVEMENTS	3. BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION	4. ALL SYSTEM IMPROVEMENTS AND ELECTRIFICATION	5. SHORE LINE BYPASS
SYSTEM REHABILITATION PROJECTS					
Penn Station/Tunnel	$ 366 M	$ 366 M	$ 366 M	$ 366 M	$ 366 M
Catenary Replacement	350	350	350	350	350
Movable Bridges	64	64	64	64	10
Peck Bridge Replacement	86	86	86	86	86
Fixed Bridges	213	213	213	213	213
SYSTEM IMPROVEMENT PROJECTS					
Harold Interlocking		65	65	65	65
Shell Interlocking		30	30	30	30
Stamford Island Platforms		30	30	30	30
New Haven Terminal Area		55	55	55	55
New Hvn-Norwalk 4th Trk		20	20	20	20
Canton Viaduct		9	9	9	9
Track Improvements		214	214	214	214
Signal System Upgrades		14	39	44	44
Grade Crossings		10	10	10	0
Station Improvements		32	32	32	32
Electrification*			445	445	445
Curve Realignments				715	450
Bypass Alignment					1180

* Electrification figure includes cost of achieving adequate bridge clearances.

NOTE: Some projects have already received initial funding by State or Federal agencies. The cost shown in this table is that portion of the total cost in excess of current and past appropriations, expressed in 1991 dollars. Values shown here generally will not agree with escalated budget figures for future years.

4.5.2 Summary of Programs

The projected minimum schedule times for all programs and rolling stock choices are summarized in Table 4-10. It must be emphasized that the values shown are attainable in principal, but their practical realization would depend not only on the validity of the numerous underlying assumptions, but also on achieving a coordinated operational environment dedicated to minimizing travel time and providing the best possible service. Equipment and fixed plant must be maintained to a high level of reliability, and scheduling must be realistic and rigorously followed. This is a daunting challenge in any public transportation system, and would be no less so on the Corridor.

TABLE 4-10. ESTIMATED MINIMUM BOSTON-NEW YORK SCHEDULE TIME (HOURS:MINUTES) AND TOTAL COST IN BILLIONS OF 1991 DOLLARS FOR EACH IMPROVEMENT PROGRAM. COST SHOWN IS THAT PORTION OF TOTAL COST FOR WHICH NO FUNDS ARE CURRENTLY APPROPRIATED, IN 1991 DOLLARS

PROGRAM: / ROLLING STOCK:	1. SYSTEM REHABILITATION	2. BASIC SYSTEM IMPROVEMENTS	3. BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION	4. ALL SYSTEM IMPROVEMENTS AND ELECT.	5. SHORE LINE BYPASS
CURRENT[1] (DIESEL/ELECTRIC)	3:47	3:07	SYSTEM FULLY ELECTRIFIED		
CURRENT/TILT	3:46	3:02	DIESEL-ELECTRIC AND GAS TURBINE		
TURBO[2]	3:48	3:21	NOT APPLICABLE		
ELECTRIC[3]	SYSTEM NOT FULLY ELECTRIFIED		2:52	2:41	2:29
ELECTRIC/TILT			2:47	2:37	2:28
HIGH-SPEED ELECTRIC[4]	ELECTRIC PROPULSION NOT		2:46	2:35	2:22
HIGH-SPEED ELECTRIC/TILT	USABLE OVER FULL ROUTE		2:41	2:33	2:21
TOTAL PROGRAM COST ($B)	$ 1.1 B	$ 1.6 B	$ 2.0 B	$ 2.7 B	$ 3.6 B[5]

Footnotes: 1. 2 F40P diesel-electric locomotives Boston-New Haven; AEM-7 electric New Haven-Boston; 10 min. change.
2. Gas turbine-powered equipment comparable to current Amtrak Empire Service.
3. 1 AEM-7 locomotive, modified for 150 MPH for Program 5; use of 2 AEM-7's improves time by 5 minutes.
4. Lightweight, high-powered equipment comparable to TGV or ABB trainsets.
5. Includes adjustment for movable bridge and curve projects made unnecessary by the bypass.

All trains consist of six coaches and make 1¼-min. stops at Back Bay, Route 128, Providence and New Haven.
Times are based on simulations, increased by 5% to allow for operational variability and uncontrollable delays.
All programs assume acceptability of higher speeds on curves than are now allowed (6" superelevation, 6" unbalance for conventional coaches and 8" for tilt suspensions) - See text.

Table 4-11, in the same format as Table 4-10, summarizes the projected incremental ridership increase for each of the programs and rolling stock alternatives associated with the trip times shown in Table 4-10. These values represent increases over a baseline of 2.3 million riders annually in 1989, which would grow to approximately 3.4 million in 2010. A large portion of the increase is due to the increased frequency of operation which would be justified by the faster service. Details of the method by which these numbers were determined are provided in Section 5.

4.5.3 Rolling Stock Costs

This scope of this study does not include development of detailed operational scenarios, precise prediction of fleet requirements, or selection of rolling stock. However, it is possible to provide an estimate of the capital cost associated with intercity cars and locomotives. The total fleet requirement to provide upgraded conventional and express (Metroliner) service with the appropriate hourly departure schedules is of the order of 30 to 40 trainsets,

TABLE 4-11. PROJECTED RIDERSHIP ON BOSTON-NEW YORK SEGMENT OF THE NORTHEAST CORRIDOR FOR EACH IMPROVEMENT PROGRAM. RIDERSHIP IN 1989 WAS 2.3 MILLION; PROJECTED 2010 RIDERSHIP WITHOUT IMPROVEMENTS IS 3.4 MILLION

PROGRAM: / ROLLING STOCK:	1. SYSTEM REHABILITATION	2. BASIC SYSTEM IMPROVEMENTS	3. BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION	4. ALL SYSTEM IMPROVEMENTS AND ELECT.	5. SHORE LINE BYPASS
CURRENT (DIESEL/ELECTRIC)	4.04	4.63	SYSTEM FULLY ELECTRIFIED DIESEL-ELECTRIC AND GAS TURBINE NOT APPLICABLE		
CURRENT/TILT	4.05	4.77			
TURBO	4.02	4.42			
ELECTRIC	SYSTEM NOT FULLY ELECTRIFIED ELECTRIC PROPULSION NOT USABLE OVER FULL ROUTE		4.91	5.22	5.51
ELECTRIC/TILT			5.04	5.32	5.58
HIGH-SPEED ELECTRIC			5.07	5.34	5.70
HIGH-SPEED ELECTRIC/TILT			5.18	5.43	5.78

depending somewhat on the level of ridership attained. Locomotives typically cost $3 million to $4 million, with coaches approximately $2 million, yielding a capital cost of approximately $20 million per trainset, depending on the technology and amenities selected. This value implies a total fleet value of the order of $700 million. However, approximately one-half of the required trainsets would be equipment already owned and in service to meet current schedules, or due for replacement regardless of Corridor improvements, so the required <u>additional</u> fleet acquisition associated with major improvements might reasonably be expected to have a capital cost in the range of $300 to $400 million, spread over 5 to 10 years as upgraded service is implemented and ridership increases.

The difference in capital cost among the various rolling stock alternatives for a given program could be as much as 10% to 20%, but is likely to be relatively small compared to the level of fixed plant expenditures associated with major improvements. Cumulative maintenance and operating costs over the service life of the equipment would be major determinants of the total expense of rolling stock ownership, further complicating the task of evaluating differences among the various cases. Trial use and extensive testing during the next few years could clarify these factors, permitting definition and acquisition of NEC equipment which is most cost-effective on a life-cycle basis.

The difference in intercity ridership projections between Program 2 and Program 5 is approximately 15%. If the frequency of departures is held constant among programs while the number of coaches per train is varied to match the ridership, a comparable variation in coach requirements is implied. Within the limits of this simplified analysis, a spread of 15% among the programs in the incremental requirement for coaches translates into a potential difference of approximately $30 million.

4.5.4 Contribution of Individual Projects to Time Savings

Table 4-12 indicates the approximate contribution of the various system improvement projects to shorter trip times, as compared to the time for Program 1. It is based on Current (Diesel/Electric) motive power in Programs 1 and 2, and Electric locomotion in Programs 3 - 5. The time reduction for the first group of projects is also dependent on the catenary upgrade and bridge rehabilitation projects included in Program 1. A more detailed discussion of the need for each project and its benefits is found in Appendix A. The capacity and reliability improvements focus on future (post-2000)

TABLE 4-12. TRIP TIME REDUCTION AND OTHER BENEFITS FOR SPECIFIC SYSTEM IMPROVEMENT PROJECTS. SAVINGS ARE WITH RESPECT TO TRIP TIMES FOR PROGRAM 1. ALL NUMBERS ARE APPROXIMATE

	Time Saving due to Higher Speeds*	Necessary for Capacity and Reliability	2. BASIC SYSTEM IMPROVEMENTS	3. BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION	4. ALL SYSTEM IMPROVEMENTS AND ELECTRIFICATION	5. SHORE LINE BYPASS
Canton Viaduct Track Improvements Signal System Upgrades Grade Crossings Station Improvements	33 min.	X	These projects, taken together, permit higher speeds--up to 130 MPH, rather than 110 MPH as for Program 1. Trip time reductions: Boston-New Haven, approx. 19 min.; New Haven-New Rochelle, 12 min.; New Rochelle to the Penn Station, 2 min.			
New Haven Terminal Area	5 min.		Improvements at the New Haven terminal will permit substantially higher approach and exit speeds in both directions, reducing trip time by approximately 5 minutes, as well as facilitating terminal-area operations.			
Stamford Island Platforms	1 min.	X	This project is essential to reduce delays, relieving congestion which intensifies conflicts at New Rochelle, and increasing capacity for commuter service. It will also permit higher speed for through trains, with a time saving of about 1 minute.			
Shell Interlocking	1 min.	X	This project is necessary to provide adequate future capacity and prevent serious delays to intercity and commuter trains at a high-traffic merge point; in addition, it will permit a higher speed and thereby save approximately 1 minute.			
Electrification	15 min.			Electrification reduces the stop in New Haven by 9 minutes since no engine change is required. The higher top speed and greater acceleration of electric locomotives permits higher speed between Boston and New Haven, gaining 6 minutes.		
Curve Realignments	11 min.				Realignment of curves is projected to shorten trip time by 11 minutes.	
Bypass Alignment	12 min.					150 MPH operation saves about 12 minutes.
New Hvn-Norwalk 4th Trk		X	This project is required in order to provide adequate capacity for the higher future levels of intercity and commuter traffic.			
Harold Interlocking		X	Harold Interlocking is the merge and intersection point between all intercity traffic and very high commuter rail traffic; separation is required in order to avoid frequent lengthy delays to both.			

* Compared to Trip Time under Program 1.

needs, although problems exist already at Stamford, Shell and Harold. This class of projects is critical to obtaining the trip times shown in Table 4-10; otherwise the likelihood of severe delays would require allowance in the schedule for substantial delays at each congested location.

4.5.5 Schedules for Intermediate Stops

A significant fraction of Boston-New York intercity passengers board or disembark at intermediate stations--particularly Providence and New Haven. Table 4-13 shows travel time to Pennsylvania Station which would result for these stations under Programs 2, 3 and 4. This table also permits estimation of trip-time improvements between intermediate points and stations south of New York; such trips account for a substantial number of the riders on the Boston-New York corridor.

TABLE 4-13. PROJECTED MINIMUM SCHEDULE TO NEW YORK FROM SOUTH STATION AND FOUR INTERMEDIATE STATIONS

PROGRAM:	2. BASIC SYSTEM IMPROVEMENTS		3. BASIC SYSTEM IMP. WITH ELECTRIFICATION		4. FULL SPEED IMPROVEMENTS	
POWER: TIME TO NYC FROM:	Diesel/Elec.	Turbo	Electric	HS Electric	Electric	HS Electric
South Station	3:03	3:21	2:46	2:41	2:41	2:35
Back Bay	3:00	3:18	2:43	2:38	2:38	2:32
Route 128	2:50	3:07	2:32	2:27	2:27	2:21
Providence	2:26	2:40	2:14	2:09	2:08	2:03
New Haven	N/A	1:02	0:57	0:54	0:54	0:53

A different set of intermediate stops--adding Stamford or excluding Back Bay, for example--has modest impact on projected trip time Based on the speed limits for Programs 2 and 3, the time contributed to the schedule by station stops--including deceleration, 1¼-minute dwell, and acceleration to authorized speed--is shown in Table 4-14. The time lost depends on the train power-to-weight ratio and speed limits in the vicinity of the station. The table is based on calculations for an electric non-tilting train; the results would differ little for any other case.

TABLE 4-14. TIME LOST IN STATION STOPS (DWELL TIME 75 SECONDS)

Station	Trip Time Impact of Station Stop (minutes)
Back Bay	1:40
Route 128	3:21
Providence	1:40
New Haven	1:47
Stamford*	2:34
New Rochelle**	2:50

* Stop not included in Program characterizations

** Stop not included in Program characterizations; may vary depending on Shell Interlocking design.

4.5.6 "Conventional" Service

Not all intercity service on an improved NEC would be the high-speed Boston-New York equivalent of current Metroliner Service. As described in Section 4, ridership of faster "conventional" or non-premium trains--8-12 coaches, 8-12 intermediate stations--is projected to provide a large fraction of the projected patronage. Table 4-15 provides estimates of trip time, under each alternative improvement program, for two rolling stock choices: current (diesel/electric) and conventional electric. (It is likely that use of turbo or advanced electric equipment, and tilt-suspension coaches would be confined to the premium service for many years.) Two operating scenarios are shown, in order to suggest the limits of likely actual cases: an eight-car train making eight intermediate stops, and a twelve-car train stopping at all twelve Amtrak stations between Boston and New York. Program 5 offers relatively little further improvement for these trains, since they have inadequate power to take advantage of the 150-MPH bypass.

TABLE 4-15. PROJECTED TRIP TIME FOR "CONVENTIONAL" SERVICE UNDER ALTERNATIVE IMPROVEMENT PROGRAMS

PROGRAM: / ROLLING STOCK AND STOPS:	2. BASIC SYSTEM IMPROVEMENTS	3. BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION	4. All SYSTEM IMPROVEMENTS AND ELECT.
2 Diesel/1 Electric, 8-cars, 8 stops	3:22		
2 Diesel/2 Electric, 8-cars, 8 stops	3:19		
2 Diesel/1 Electric, 12-car, 12 stops	3:43		
2 Diesel/2 Electric, 12-car, 12 stops	3:38		
1 Electric, 8-car, 8-stops		3:06	2:55
2 Electric, 8-car, 8-stops		2:57	2:46
1 Electric, 12-car, 12 stops		3:38	3:20
2 Electric, 12-car, 12 stops		3:12	3:01

5. BENEFITS FROM IMPROVED BOSTON-NEW YORK RAIL SERVICE

Improving the speed and quality of rail service in the Boston-New York portion of the Northeast Corridor offers potentially substantial benefits to today's rail travelers and new passengers attracted by improved train service, as well as to travelers who continue to use other modes. Current users of both Amtrak intercity service operating in the Corridor and commuter railroad services provided by transit authorities along the Corridor will benefit directly from faster and more reliable travel. At the same time, improvements in the speed and reliability of corridor rail service will attract new passengers who previously traveled by automobile or airline, and may induce some travelers to make entirely new rail trips within the Corridor. These new rail travelers also receive important benefits from the availability of faster and more reliable rail travel, as evidenced by the increased number who elect to use the improved service for their trips.

Continuing users of highways and airports serving the Boston-New York corridor may also benefit indirectly from the improvement in rail service. Insofar as the diversion of some automobile and airline travel to improved rail service reduces congestion levels on highways and at airports serving the Corridor, automobile and air travelers will also benefit from slightly faster travel times. Finally, some of the direct benefits received by current and new rail travelers may be captured by Amtrak in the form of higher fare revenues. While this does not increase the total benefits from improved rail service (it simply transfers part of them from rail riders to Amtrak), it may contribute to Amtrak's earnings from Northeast Corridor operations and thereby reduce its dependence on federal operating subsidies.

This study does not attempt to provide a comprehensive benefit-cost analysis of the range of possible improvements to Northeast Corridor rail service, nor does it enumerate all of the potential benefits from increasing the speed and reliability of rail travel. However, it does provide empirical estimates of the major categories of benefits that would result from improving Boston-New York rail service. These include time savings to intercity and commuter rail passengers traveling within the Corridor, direct benefits to former highway and air travelers who elect to use the improved rail service, and indirect (or "external") benefits to those continuing to travel by other modes. Further, it illustrates how each of these categories of benefits would be expected to increase with progressively more extensive and costly improvement programs, and compares these increases to the additional investments entailed by each of these programs. This comparison provides valuable information to inform public officials' deliberations and final choice among these alternate improvement programs.

5.1 TRAVEL TIME SAVINGS FROM IMPROVED RAIL SERVICE

5.1.1 Projected Travel Time Improvements

Table 5-1 summarizes the range of improved travel times between Boston's South Station and New York's Penn Station corridor that is anticipated to result from each improvement program. It also compares these to current scheduled times for Amtrak's "New England Express" and conventional trains, and shows that significant reductions in travel time for both high-speed and conventional service are anticipated to result from each improvement program.

TABLE 5-1. CURRENT AND IMPROVED TRAVEL TIMES FOR BOSTON/SOUTH STATION TO NEW YORK/PENN STATION (HOURS:MINUTES)

Type of Service	1990 Actual	Range of Year 2010 Estimated Rail Travel Times*: Baseline	Program 2	Program 3	Program 4	Program 5
High-Speed	3:55	3:46-3:48	3:02-3:21	2:41-2:52	2:33-2:41	2:21-2:29
Conventional	4:50	4:35-4:47	3:38-3:43	3:12-3:38	3:01-3:20	3:01-3:20

* Range shown is for different equipment options available under each program. High-speed service is assumed to make four stops between Boston and New York, and conventional service twelve stops.

Sources: AMTRAK Spring-Summer 1991 Timetable; Train Performance Calculator simulations.

As discussed previously in Chapter 4, the range of high-speed rail trip times shown for each improvement program corresponds to the exact equipment option chosen under each program, and is partly responsible for the range of ridership figures shown subsequently for each program. (Conventional rail service does not show a corresponding variation because it is assumed to be operated with existing diesel and electric equipment, depending upon the improvement program chosen.) The improved travel times shown in Table 5-1 provide the basis for estimating the travel time savings and for forecasting the increases in future rail ridership and resulting benefits presented in this chapter.

5.1.2 Time Savings for Amtrak Passengers

Intercity rail travelers carried by today's Amtrak services are likely to realize significant benefits from faster operating speeds made possible by the combination of track and station improvements, bridge reconstruction, and various other speed-enhancing projects included in each of the improvement programs detailed in this report. Each improvement program will also facilitate shorter scheduled travel times by eliminating minor delays that now recur at critical track sections, bridges, stations, and junctions, since published schedules include an allowance for the cumulative effect of minor delays typically encountered during a trip. Many of these projects are also likely to increase the reliability with which scheduled travel times are actually met on a day-to-day basis, by reducing the frequency with which major delays result from traffic conflicts, equipment failures, or other causes related to the condition or capacity of the corridor.

While the exact operating scheme to be employed by Amtrak once the capability to operate high-speed service between Boston and New York is established remains uncertain, it seems likely to incorporate a mix of high-speed, express or limited-stop services modeled after current New York-Washington Metroliners, together with trains making more frequent stops and requiring somewhat longer scheduled times to complete the Boston-New York trip. Because each of the improvement programs discussed previously would facilitate faster and more reliable travel by high-speed as well as conventional trains, current rail travelers who utilize the new high-speed service as well as those who continue to travel on conventional trains would benefit as a result. Although rail passengers attracted by the new availability of high-speed service would experience the largest travel time savings by comparison to unimproved Boston-New York service, passengers on conventional trains would also benefit from substantial reductions in pre-improvement program travel times.

Table 5-2 presents potential time savings for Amtrak intercity passengers expected to travel in the Boston-New York corridor during the year 2010. Annual time savings are estimated for the anticipated reductions in high-speed and conventional rail travel times resulting from Programs 2, 3, 4, and 5, detailed previously in this report. The aggregate passenger time savings anticipated for each program are expressed relative to the baseline that would be established by Program 1, which includes rehabilitation projects only. As the table indicates, travel time savings under each improvement program are expected to result from a combination of diversion of some year 2010 rail riders to the new high-speed

TABLE 5-2. ESTIMATED TIME SAVINGS FOR BOSTON-NEW YORK AMTRAK PASSENGERS: SYSTEM IMPROVEMENTS VERSUS REHABILITATION ONLY

Measure	Travel Time Savings versus Program 1: Program 2	Program 3	Program 4	Program 5
Reduction in Boston-New York Trip Time:*				
High-Speed Service	0:25-0:44	0:54-1:05	1:07-1:13	1:19-1:25
Conventional Service	0:57-1:07	1:09-1:23	1:27-1:34	1:27-1:34
Total Time Saving (million hours/year)	2.3-3.6	3.9-4.2	4.6-4.8	4.9-5.2
Dollar Value @ $15 per Hour (millions of 1991 dollars/year)	$34-54	$59-64	$69-73	$74-78

* Reduction in scheduled travel time between South Station and Penn Station compared to Program 1 (rehabilitation projects only).

Source: Calculated from projected schedules and ridership forecasts described in text.

service, together with significant trip time reductions for passengers who continue to utilize conventional trains. (The range of possible time savings shown for each program reflects the effect of the various rolling stock options on the travel times attained by high-speed service. It is important to note that the higher performance rolling stock necessary to achieve larger time savings is likely to require a higher initial capital investment.)

Travel time savings to the 3.8 million Amtrak passengers expected to travel within the Boston-New York corridor during 2010, even in the absence of major service improvements, are projected to range from 2.3 to 3.6 million hours per year for the Basic System Improvement Program (Program 2). The corresponding range would increase considerably--to 3.9-4.2 million hours annually--with the addition of electrification (Program 3), reflecting the significant improvements in both high-speed and conventional train running times expected to result. Table 5-2 also shows that aggregate time savings are projected to rise to 4.6-4.8 million hours per year with the addition of various curve-straightening projects (Program 4), and slightly further to the 4.9-5.2 million hour range with adoption of the Shore Line bypass alignment (Program 5).

When valued at $15 per hour, the table shows that these time savings range from $34-54 million annually for Program 2, to as much as $74-78 per year for the most ambitious program (Program 5). The $15 hourly value for time savings experienced by intercity rail travelers is consistent with the results of recent research on intercity travel behavior, which suggests that values of intercity travel time range between 50% and 150% of travelers' hourly wage rates. (For example, see Stephen A. Morrison and Clifford Winston, "An Econometric Analysis of the Demand for Intercity Passenger Transportation," Research in Transportation Economics, Volume 2, 1985, pp. 213-237, and Don H. Pickrell, "Models of Intercity Travel Demand," in John R. Meyer and Clinton V. Oster, eds., Deregulation and the Future of Intercity Passenger Travel, MIT Press, 1987.)

5.1.3 Time Savings for Commuter Rail Passengers

Certain track, bridge, and station reconstruction projects included in each improvement program will enable faster commuter rail service to be operated over the portions of the corridor used jointly by intercity and commuter trains. The benefits from time savings and increased reliability for individual commuter rail trips are likely to be small by comparison to those experienced by intercity rail passengers, since commuter trips each cover only a small portion of the full Boston-New York corridor. (The longest commuter rail trips utilize only about 55 miles of the full 231-mile Boston-New York corridor.) However, the aggregate benefits from time savings experienced by commuters may still be substantial, because the volume of commuter rail trips in the corridor is large by comparison to the number of intercity trips carried by Amtrak services.

Table 5-3 reports estimated potential annual time savings experienced by passengers on Boston and New York-area commuter rail services that utilize the improved corridor. These include service operated by Boston's MBTA on its Attleboro-Stoughton line, and by the New York area's Metro-North Commuter Railroad on its New Haven Line. Time savings are estimated for the number of riders forecast by the MBTA and Metro-North to utilize their respective commuter rail services during the year 2010, which reflect long-term historical growth rates applied to current ridership levels. As with the previous estimates for intercity rail passengers, Table 5-3 reports estimated time savings for the various improvement programs, using as a baseline the travel times that would result from the program of rehabilitation projects (Program 1).

These estimated savings assume that commuter rail services sharing the improved corridor are operated in a manner that takes full advantage of the top speed increases facilitated by the various rehabilitation and improvement projects, yet minimizes interference with the increased volume of Amtrak intercity trains utilizing the improved corridor. Attaining these potential time savings may require the urban transit operators that provide commuter rail

TABLE 5-3. ESTIMATED TRAVEL TIME SAVINGS FOR COMMUTER RAIL PASSENGERS: CORRIDOR IMPROVEMENTS VERSUS REHABILITATION ONLY

Measure	Time Savings versus Program 1: Program 2	Program 3	Program 4	Program 5
Boston-Area Commuters:				
Daily Riders Affected	24,300	24,300	24,300	24,300
Average Time Savings per One-Way Trip (minutes)	1.6	4.9	4.9	4.9
Total Annual Time Savings (million hours)	0.34	1.04	1.04	1.04
Dollar Value @ $5-10/hr. (millions of 1991 $/yr.)	1.7-3.4	5.2-10.4	5.2-10.4	5.2-10.4
New York-Area Passengers:				
Daily Riders Affected	79,200	79,200	79,200	79,200
Average Time Saved per One-Way Trip (minutes)	12.8	12.8	12.8	12.8
Total Annual Time Savings (million hours)	4.71	4.71	4.71	4.71
Dollar Value @ $5-10/hr. (millions of 1991 $/yr.)	23.6-47.1	23.6-47.1	23.6-47.1	23.6-47.1

Source: Calculated from commuter rail ridership forecasts supplied by MBTA and Metro-North and Train Performance Calculator simulations of commuter train running times under various improvement programs.

service in the corridor to make additional investments in equipment beyond those identified in this report and not included in the improvement program cost estimates reported previously. For example, attaining the travel time benefits offered by electrification would require the MBTA to acquire a fleet of electric locomotives adequate to serve its Attleboro/Stoughton and Franklin lines.

As Table 5-3 shows, the corridor improvements detailed in this study offer potential travel time savings for the more than 24,000 daily commuters projected to use two Boston-area commuter rail lines during the year 2010 ranging from 0.3 million to more than 1 million hours annually. The lower figure is associated with Program 2, which results in minimal time savings (approximately 1.6 minutes per trip) for riders on the Attleboro-Stoughton line because it includes reconstruction of the Canton Viaduct. The higher figure, which averages nearly 5 minutes per one-way trip, is projected to result from electrification of the corridor, which could markedly improve acceleration and top speeds of MBTA commuter trains operating on the Boston-Providence segment of the Amtrak main line.

Since no further improvements in commuter train schedules are anticipated beyond those resulting from electrification, which is included in Program 3, estimated time savings for MBTA commuter passengers do not increase further for Programs 4 or 5. Nevertheless, the estimated time savings represent 6% to 20% of Boston-area commuter rail passengers' projected aggregate year-2010 travel time if only the rehabilitation projects comprising Program 1 were completed. Valued at $5-10 per hour, a reasonable range based on recent research, these time savings would amount to $1.5-3.0 million in annual benefits under Program 2, and $5.0-10.0 million annually for each of the improvements programs that entail electrification (Programs 3, 4, and 5). (An extensive body of research suggests that urban commuters value travel time at hourly rates ranging from 25% to 40% of their average wage rates. For the comparatively high income levels that characterize commuter rail riders in most urban areas, this implies values of travel time savings in the $5-10 per hour range.)

Table 5-3 also reports that aggregate travel time savings of some 4.7 million hours are possible for the nearly 80,000 Connecticut and New York commuters anticipated to travel daily during the year 2010 over the 55-mile portion of Metro-North Commuter Railroad's New Haven Line shared by Amtrak intercity service. These savings, which average nearly 13 minutes per commuter trip, would represent approximately 11% of projected year-2000 aggregate travel time for those commuters at the scheduled travel times expected to result from completing only the rehabilitation projects comprising Program 1. For Metro-North commuters, travel time savings would result primarily from the track and station improvement projects included in Program 2. Thus as Table 5-3 indicates, projected total time savings are identical for Programs 2 through 5. Valued at the $5-10 per hour figure, these time savings represent additional benefits beyond those from basic rehabilitation of the corridor (Program 1) ranging from $23.5 to $47.0 million per year. In total, potential time savings to Boston and New York-area commuter rail passengers ranges upward from 5 million hours annually, depending upon the specific improvement program chosen, with a collective monetary value ranging from $25 million to as much as $50 million per year. These potential time savings are of the same order of magnitude as those estimated for all Amtrak intercity passengers traveling within the Boston-New York corridor. As indicated previously, however, the estimated time savings for commuters must be regarded as the maximum achievable for each level of investment in improved corridor rail service. Realization of those savings will require a combination of careful scheduling and operations control by commuter rail agencies, close cooperation between those agencies and Amtrak, and potentially significant additional investments in higher performance rolling stock by commuter agencies.

5.2 IMPROVED PASSENGER COMFORT AND CONVENIENCE

Some projects contributing to higher rail speeds or more reliable schedule adherence are also likely to increase the comfort or convenience offered by rail travel. Examples include track and bridge improvements that contribute to a more comfortable on-board ride for passengers, upgraded or modernized passenger facilities and baggage-handling capabilities at stations, and acquisition of equipment offering more comfortable passenger seating or more convenient access and egress. Although the resulting improvement in passenger convenience and comfort is difficult to evaluate in terms that are conformable with other measures of benefit from faster and more reliable service (such as travel time savings), it nevertheless represents a potentially significant source of additional benefits from investment in improved corridor rail service.

5.3 INCREASED RAIL RIDERSHIP

In addition to current users of Amtrak and commuter rail service within the Boston-New York corridor, new intercity rail passengers attracted by the prospect of faster and more reliable rail service represent a major category of beneficiaries from the corridor improvement program. New rail passengers drawn from competing intercity travel modes--commercial airline service and the private automobile--by faster and more reliable train service receive better transportation service, as demonstrated by their decisions to switch to rail from their present modes of travel. Although some of these new rail travelers may actually experience slightly slower door-to-door trip times than provided by their previous travel modes, they will nevertheless be better off on balance as a result of the combination of travel time, cost, convenience, and other features of improved rail travel. While the majority of new riders are likely to be attracted by the availability of high-speed rail service, improving the speed and reliability offered by conventional trains is also likely to provide an important source of ridership growth.

5.3.1 The Question of "Induced" Travel

Travelers who are induced by the availability of faster and more reliable train service between Boston and New York to make entirely new rail trips within the corridor also represent important potential beneficiaries of improved train service. The number of such "induced" trips is notoriously difficult to anticipate, partly because it includes some trips with discretionary destinations (such as vacation travel) currently being made to points outside the corridor, which are drawn by improved service to destinations accessible via the improved corridor train service. In addition, it includes entirely new travel prompted by the availability of high-speed train service, which is often equally difficult to predict. Although the difficulty of forecasting accurately the number of trips likely to be induced by faster Boston-New York rail travel has prompted their exclusion from the forecasts reported below, the benefits from induced travel represent a potentially important additional source of total benefits from improved corridor rail service.

5.3.2 Forecasting Increased Rail Ridership

Forecasts of Boston-New York rail ridership were developed for the improved travel times and conditions anticipated to result from each of the alternative improvement programs detailed in previous sections of this report. These forecasts were produced by using ridership models developed as part of high-speed rail ridership studies performed in Florida and Texas. One feature of these models that makes them ideally suited for projecting increased corridor rail ridership is their explicit incorporation of competition between existing airline service and potential high-speed rail service for business travel, and between the private automobile and potential high-speed rail service for vacation and other nonbusiness travel. In addition, they allow potential rail travelers to choose between high-speed rail service offered at premium fares, and lower fare rail service offering travel times that, while slower than those for express-type service, still represent a significant improvement from current Boston-New York schedules.

5.3.3 Projected Boston-New York Service Levels

Rail service between Boston and New York after completion of each improvement program is anticipated to be operated much like that currently provided by Amtrak in the New York-Washington portion of the corridor, particularly for those programs (Programs 3, 4, and 5) that entail electrification from New Haven north to Boston.

This includes both express and limited-stop service operating at high speeds, much as Metroliners now operate over the electrified portion of the corridor, together with conventional trains making more frequent stops and operating at lower top speeds.

In forecasting year-2010 ridership for the baseline travel times established by Program 1 as well as those made possible by each improvement program, conventional and Metroliner-type service between Boston and New York are each assumed to operate at hourly intervals over a 15-hour period each weekday. Slightly more frequent high-speed service is assumed to be offered during peak periods by scheduling one additional Boston-New York express departure in each direction, an operating scenario again patterned on that now used by Amtrak south of New York. This represents a significantly increased level of service from the present weekday schedule of ten conventional trains in each direction, with "New England Express" trains departing Boston twice during morning hours and New York twice during afternoon hours. While it might be more realistic to assume that service frequency would increase gradually with the progressive reduction in travel time permitted by the more ambitious improvement programs, uniform frequencies were employed in order to isolate more clearly the contribution to increased rail ridership made by successively faster travel times over the baseline times made possible by Program 1.

5.3.4 Rail Fare Assumptions

Fares for rail service are also assumed to be patterned after those now charged by Amtrak in the New York-Washington segment of the corridor. Analysis of published fare schedules indicates that undiscounted coach fares between stations south of New York presently average $0.28 per mile for conventional services, while for Metroliner service, fares consist of a "fixed charge" of approximately $8.00 plus $0.34 per mile. On this basis, undiscounted fares for the 231-mile trip between Boston's South Station and Penn Station in New York would be approximately $86 for high-speed rail travel, and $65 for conventional service. These fares amount respectively to about 60% and 45% of the current undiscounted fare ($142.50) for air shuttle service between Boston's Logan Airport and New York's LaGuardia Airport.

While discounts offered by Amtrak for purchasing tickets in advance, traveling during off-peak periods, and meeting various other restrictions on travel would lower the average fare actually paid by users of the two services below these undiscounted levels, it is difficult to estimate by exactly how much. Further, effective yield management would adjust these restrictions to prevent most of those who are willing to pay full coach fares from taking advantage of discount offers. At the same time, current airline fares for Boston-New York appear sufficiently high to permit airlines considerable latitude for "strategic" fare discounting in response to the introduction of high-speed rail service at fares well below current air fares.

To account for the uncertainty inherent in forecasting the relationship of fares for improved rail service to future airline fares, a range of rail ridership estimates was prepared for each improvement program, based on different assumptions about the future relationship between rail and airline fares. (As indicated previously, the range of possible travel times associated with different equipment options under each improvement program also contributes to this range.) Rail ridership forecasts were first prepared for the fare structure currently prevailing for New York-Washington service. As noted above, this assumption produces high-speed and conventional rail fares equal to 60% and 45% of current air shuttle charges.

Additional ridership estimates were then generated using fares for high-speed rail service between Boston and New York set at 70% and 80% of the current Logan-LaGuardia air shuttle fare. In each case, the current relationship between conventional and high-speed rail fares was assumed to be maintained. Business travelers were assumed to pay these full fare levels when using both high-speed and conventional rail service, while vacationers and other non-business travelers were assumed to be offered discounts that reduce these full fares by up to 25%, approximately the degree of discounting embodied in AMTRAK's current fare structure. Fares for origin-destination pairs lying between Boston and New York were set as proportions of the high-speed and conventional fares for Boston-New York travel on a distance prorated basis.

5.3.5 Costs and Service Levels for Competing Modes

In developing forecasts of rail ridership for the Boston-New York corridor, the future costs and travel times offered by competing travel modes were assumed to remain at current figures. (Auto costs and air fares were assumed to remain constant in "real" or inflation-adjusted terms.) Because congestion levels on highways and at major airports serving the corridor seem likely to increase with continuing growth in the volume of intercity travel, the assumption of constant door-to-door travel times for highway and air travel should contribute to conservative forecasts of travel on an improved rail system. The assumption that real auto operating costs will remain constant is less conservative, although barring major disruptions in energy supplies it appears to be the most realistic trend to expect.

5.3.6 Year 2010 Baseline Rail Ridership

Table 5-4 reports current rail ridership in the Boston-New York corridor, together with ridership projected to occur during 2010 under Program 1, which includes only rehabilitation projects within the corridor. The latter measure subsequently forms the baseline against which ridership growth in response to travel time improvements is measured. As the table indicates, ridership growth in the four major markets within the Boston-New York corridor is projected to increase by 84% from its actual level during 1988, with the largest increase projected to occur in travel between Boston and New York City. When anticipated growth in other trips with both origin and destination within the Boston-New York corridor and in trips passing through New York are included, total rail trips are projected to grow from 2.3 million during 1988 to 3.8 million by 2010, a 63% increase. The projected year 2010 ridership level is expected to consist of 25-30% trips for business-related purposes, with the remaining 70-75% representing travel for a variety of other purposes such as vacationing, visiting relatives, or attending school.

The difference between current and future baseline ridership shown in the table stems from three sources: demographic and income growth within the corridor between now and the year 2010; slight improvements in both New England Express and conventional train running times due to the rehabilitation program; and more frequent express and conventional train service than is now provided. Of these three factors, demographic growth is expected to account for the largest share of ridership growth from its current level to that anticipated during the year 2010 with only the rehabilitation projects completed.

5.3.7 Forecast Ridership with Improved Travel Times

Table 5-5 compares the baseline (Program 1) forecast of year 2010 rail ridership with those for each of the four corridor improvement programs (Programs 2, 3, 4, and 5). The table reports a range of possible ridership for each level of improved travel time, reflecting the different rail fare assumptions discussed previously. (Baseline year 2010 ridership was estimated using current rail fares.) As Table 5-5 indicates, the projected effect of improved rail travel time on total corridor rail travel is quite pronounced.

TABLE 5-4. CURRENT AND YEAR 2010 FORECAST RAIL RIDERSHIP IN THE BOSTON-NEW YORK CORRIDOR (THOUSANDS)

Market Segment	1988 Actual	2010 Baseline (Program 1)	% Growth
Boston-New York	714	1,392	95%
Boston-New Haven	115	172	49%
Providence-New York	189	313	66%
Providence-New Haven	23	35	52%
Subtotal	1,041	1,912	84%
Others North of New York*	821	1,342	64%
Trips Through New York**	475	560	18%
Total	2,337	3,814	63%

* Trips with both origin and destination north of New York. Includes travel between Springfield-Hartford branch and points within corridor.

** Trips with either origin or destination north of New York but other end south of New York.

TABLE 5-5. YEAR 2010 FORECAST AMTRAK RIDERSHIP IN BOSTON-NEW YORK CORRIDOR (MILLIONS)

Market Segment	Baseline/ Program 1	Program 2	Program 3	Program 4	Program 5
Boston-New York	1.39	1.77-1.86	2.00-2.13	2.15-2.25	2.28-2.42
Boston-New Haven	0.17	0.17-0.18	0.17-0.18	0.18	0.18
Providence-New York	0.31	0.36-0.37	0.38-0.40	0.40-0.41	0.41-0.43
Providence-New Haven	0.04	0.04	0.04	0.04	0.04
Subtotal	1.91	2.34-2.45	2.60-2.74	2.76-2.87	2.91-3.06
Others North of New York*	1.34	1.47-1.53	1.63-1.72	1.73-1.80	1.83-1.92
Trips Through New York**	0.56	0.61-0.64	0.68-0.72	0.72-0.75	0.76-0.80
Total	3.81	4.42-4.63	4.92-5.17	5.22-5.43	5.51-5.78

* Trips with both origin and destination north of New York. Includes travel between Springfield-Hartford branch and points within corridor.

** Trips with either origin or destination north of New York but other end south of New York.

Total rail ridership in the Boston-New York corridor is projected to range from 4.4 to 4.6 million trips annually under Program 2, which results in high-speed and conventional rail travel times between Boston-South Station and New York-Penn Station of 3:07 and 3:38 (using the conventional diesel and electric equipment now operating between Boston and New York; see Table 5-3).

Annual rail ridership in the corridor is forecast to increase to the 4.9-5.2 million range with electrification of the Boston to New Haven segment of the corridor (Program 3), which enables high-speed service between downtown Boston and New York to improve to under 3 hours (2:52 with a conventional electric locomotive). Much of the substantial difference in ridership between the program of basic speed improvements (Program 2) and Program 3 results from the significant improvement in conventional train performance that is also made possible by electrification. This is reflected in the anticipated reduction of conventional train running times between South Station and Penn Station to a figure potentially as low as 3:12 mark with electrification (see Table 5-3).

Table 5-5 also shows that improving high-speed and conventional train running times further to 2:40 and 3:01, the product of curve straightening added by Program 4, could raise annual ridership in the Boston-New York corridor to as high as the 5.2-5.4 million range. Finally, with the potential reduction in Boston-New York travel time on high-speed rail service made possible by the Shore Line bypass route, annual corridor ridership is projected to increase further to the 5.5-5.8 million range. These potential ridership increases represent substantial growth from the 3.8-million trip baseline (Program 1) forecast for the Boston-New York corridor. However, it is important to recall that they are the product of dramatic reductions in travel times for both high-speed and conventional rail service between Boston and New York, together with very significant increases in the frequency of both types of service expected to be operated by Amtrak after an improvement program is completed.

The progressive improvements in travel times from Programs 2 through 5 are expected to increase the attractiveness of rail service to business travelers, resulting in a gradual increase in the share of rail trips that represents business travel. With high-speed service in the 3-hour range (Programs 2 and 3), the fraction of total rail ridership consisting of business travelers is expected to rise from the baseline level (25-30%) to one-third or slightly more. As rail travel times are further reduced by the more extensive corridor improvements included under Programs 4 and 5, as many as 38-40% of total rail ridership is expected to be comprised of business travelers, with the remainder of riders traveling for vacation and a variety of other purposes. As would be expected, under each improvement program a somewhat higher fraction of high-speed ridership would represent business travel, although considerable business travel is still anticipated on conventional rail service.

5.3.8 High-Speed Versus Conventional Ridership

Table 5-6 shows the mix of passengers expected to use high-speed and conventional rail services under each of the four improvement programs. As it indicates, forecast ridership is anticipated to be fairly evenly balanced between conventional and high-speed services under each of the improvement programs. Under Program 2, which offers a much greater reduction in travel times for high-speed than for conventional rail service, the former service is forecast to carry 54-56% of total corridor rail travel. When electrification is added to these basic speed improvements (as in Program 3), however, the forecast mix of ridership is anticipated to be 57-59% on the high-speed service and the remaining 41-43% on conventional trains. Program 4, which is anticipated to reduce Boston-New York running times for both services by an additional 11 minutes, is expected to result in approximately a 60% share of total rail travel for the high-speed service. Finally, this figure is anticipated to increase slightly further--to the 61-63% range--under the Shore Line Bypass Program, as the table indicates.

TABLE 5-6. FORECAST DISTRIBUTION OF RAIL RIDERSHIP BETWEEN HIGH-SPEED AND CONVENTIONAL SERVICE (PERCENT)

Service Type	Baseline/ Program 1	Program 2	Program 3	Program 4	Program 5
High-Speed	49%	54-56%	57-59%	59-60%	61-63%
Conventional	51%	44-46%	41-43%	40-41%	37-39%

5.3.9 Diversion of Travelers from Auto and Air

Table 5-7 reports the distribution of new riders projected to be attracted to the improved rail service between those who formerly traveled by automobile and those previously using commercial airline service in the corridor. As it shows, much of the growth in rail travel in response to improved travel times is expected to be drawn from current airline users, particularly for the highest speed rail services considered in this study. The table indicates that nearly 80% of the new riders attracted to both high-speed and conventional rail service by the travel time improvements resulting from Program 2 are expected to be former airline travelers, with the remainder of new riders (slightly more than 20% on each type of service) drawn from automobiles.

The proportion of riders drawn from airline travel is anticipated to increase only slightly with the further travel time improvements resulting from electrification (Program 3), curve realignment (Program 4) and the Shore Line Bypass (Program 5). This finding reflects the fact that improved rail service is expected to appeal primarily to time-sensitive business travelers, who now predominantly choose to travel by air. Nevertheless, the anticipated diversion of nonbusiness air travelers--whose travel behavior also reveals comparatively high values of travel time--to improved Boston-New York train service also represents an important source of new rail ridership.

TABLE 5-7. MODES FORMERLY UTILIZED BY NEW RAIL RIDERS DIVERTED BY CORRIDOR IMPROVEMENT PROGRAMS (PERCENT)

Service Type	Former Mode	Program 2	Program 3	Program 4	Program 5
High-Speed	Auto	21%	19%	18%	17%
	Air	79%	81%	82%	83%
Conventional	Auto	22%	20%	19%	18%
	Air	78%	80%	81%	82%

5.3.10 Economic Benefits to New Rail Riders

The conventional economic or dollar index of the benefits received by travelers who are drawn to improved rail service from another mode represents travelers' valuation of the improved service, as measured by their collective willingness to pay higher fares to use it. Viewed another way, this index expresses the dollar value to new passengers of the improvements in its performance characteristics--speed, reliability, convenience, etc.--that induced them to make new trips by rail. (For a comprehensive discussion of the theoretical basis, interpretation, and actual computation of consumer surplus, as this measure is known, see E.J. Mishan, Cost-Benefit Analysis, Praeger Publishers, 1976, Chapters 7-9.) For each improvement program considered, this measure can be calculated from the resulting improvement in rail travel times, the anticipated number of new rail riders, and the hourly value of travel time to users of the competing modes from which they are expected to be drawn (auto and air).

Table 5-8 reports the estimated value of economic benefits to new riders of improved Boston-New York rail service expected under Programs 2-5, again measured against the baseline established by Program 1. As it indicates, these benefits are expected to lie in the $20 million range under the Basic System Improvement Program (Program 2), but could rise to more than double that amount with fully electrified Boston-New York service (Program 3). With the further improvements offered by Program 4, economic benefits to rail riders diverted from competing modes could rise to as much as $60 million annually. Finally, the dollar value of benefits to new rail riders could exceed the $70 million mark with the further travel time reductions afforded by the Shore Line Bypass Program (Program 5), as the table shows.

TABLE 5-8. ECONOMIC BENEFITS TO NEW RAIL RIDERS (MILLIONS OF 1991 DOLLARS PER YEAR)

	Benefits to New Riders of Service Under:			
Service Type	Program 2	Program 3	Program 4	Program 5
High-Speed Rail	$8-12	$19-27	$28-34	$37-47
Conventional Rail	$10-11	$20-22	$25-26	$26-27
Total	$18-23	$40-49	$53-60	$63-74

5.4 "INDIRECT" BENEFITS GENERATED BY FASTER RAIL TRAVEL

The direct effects of faster service on rail travel times and ridership are also likely to generate a variety of secondary or indirect benefits. These include changes in the financial performance of agencies operating rail service over the improved portion of the Corridor (both Amtrak and the transit agencies providing commuter rail service), reductions in congestion and resulting delays on parallel travel facilities (highways or airports, for example), possible environmental quality improvements, altered land use patterns, and stimulus to regional economic development.

Some of these indirect or "downstream" impacts--most notably reductions in delays experienced by users of competing facilities and reductions in the contribution of intercity travel to air pollution and other environmental damage--do represent potentially significant additional benefits of increased reliance on rail service for intercity travel. Most other secondary impacts, however, simply represent other forms into which direct benefits are translated as they circulate through the region's economy and thus do not increase total benefits from investing in faster rail travel, although they may provide convenient alternate ways of measuring these impacts.

This report focuses on estimating the most important categories of indirect benefits likely to result from the various investment programs for rail service improvements. These include travel time savings stemming from the potential reductions in highway and airport congestion in response to diversion of intercity trips from automobiles and commercial airline service to high-speed rail service. (Only the change in congestion levels on existing parallel transportation facilities is considered, since the level and timing of investment in the number or capacity of other transportation facilities is a separate issue.) In addition, it examines the possible effect of improved service on passenger revenues and operating profits earned by Amtrak on its operation of intercity rail service in the Northeast Corridor.

5.4.1 Time Savings to Continuing Highway and Airport Users

Corridor travelers who continue to drive or fly may experience slightly faster travel from reductions in highway and airport congestion prompted by diversion of some trips from these modes to improved train service. These reductions in the congestion-related time delays imposed on one another by highway and by airport users represent the relevant measure of indirect benefits from diverting highway and air travelers to improved rail service. Postponement or cancellation of pending investments in expanded capacity of airports or highways in response to their reduced utilization and the resulting congestion cannot also be counted as an additional benefit of diverting travel from these facilities. This is because any such decision necessarily also entails deferring or foregoing the benefits that would have resulted from that investment (which were presumably at least sufficient to justify the pending investment decision), and would require counting this sacrifice as a corresponding cost of the decision.

Because the models used to develop these rail ridership forecasts explicitly estimate diversion of travelers from air and automobile modes to improved rail service, it is possible to estimate the potential magnitude of these time savings. For automobile travelers, these savings were estimated by calculating the increase in driving speeds on two major highway routes between the Boston and New York metropolitan areas (Interstate Route 95 via Providence and New Haven, and Interstate Routes 90 and 84 via Worcester and Hartford) resulting from diversion of some former drivers to high-speed rail service. These calculations assume that one-half of automobile trips diverted to the improved rail service would have occurred during those hours when traffic congestion is most prevalent on these routes. Although the projected increases in travel speeds are very slight on most segments of these highway routes, the resulting aggregate time savings can still be significant because the number of vehicles experiencing these speed increases is large.

Table 5-9 reports the estimated annual travel time savings to users of Boston-New York highway routes. As it shows, their aggregate value ranges from 0.03 to as much as 0.11 million hours each year for the numbers of vehicles projected to utilize these routes during the year 2010, with the estimate increasing as more highway travelers are attracted by continuing improvements in rail service. Because most vehicles traveling on even rural segments of Interstate Highway routes are making local trips rather than long-distance intercity journeys, much of these potential travel time savings would be experienced by residents of the communities lying along these routes, rather than by Boston-New York travelers.

TABLE 5-9. ESTIMATED TIME SAVINGS TO USERS OF BOSTON-NEW YORK HIGHWAY ROUTES AND AIRPORTS RESULTING FROM RAIL DIVERSION

	Change in Measure versus Program 1:			
Impact Measure	Program 2	Program 3	Program 4	Program 5
Auto Travelers:				
Trips Diverted to Rail (millions/year)	0.08-0.12	0.17-0.21	0.21-0.24	0.25-0.29
Time Savings to Highway Users (million hours/year)	0.03-0.04	0.05-0.07	0.07-0.08	0.09-0.11
Dollar Value @ $10/hr. (millions of 1991 $/yr.)	$0.3-0.4	$0.5-0.7	$0.7-0.8	$0.9-1.1
Air Travelers:				
Trips Diverted to Rail (millions/year)	0.30-0.47	0.71-0.93	0.97-1.15	1.22-1.46
% Decline in Airport Use:				
Boston-Logan	4.2-4.6%	5.3-5.9%	5.9-6.4%	6.6-7.2%
New York-LaGuardia	2.3-2.6%	2.9-3.2%	3.3-3.5%	3.6-3.9%
New York-Newark	1.4-1.5%	1.7-1.9%	2.0-2.1%	2.2-2.4%
New York-Kennedy	0.9-1.1%	1.2-1.4%	1.4-1.5%	1.6-1.7%
Time Savings to Airport Users (million hours/year)	0.3-0.7	0.4-0.8	0.5-0.9	0.6-1.0
Dollar Value @ $30/hr. (millions of 1991 $/yr.)	$9-20	$12-23	$14-26	$18-29

Sources: Calculated from forecast highway travel volumes supplied by state Departments of Transportation and Federal Aviation Administration, and estimated diversion of highway and air travelers to high-speed rail service, using procedures described in text.

In addition, since a substantial fraction of travel on major intercity highways represents truck movements rather than automobile trips, a corresponding fraction of these benefits would accrue to shippers rather than to highway travelers themselves. Depending on the characteristics of the commodities being transported, however, these time savings may be considerably more valuable (at least on an hourly basis) than those experienced by automobile travelers. If a composite value for travel time savings experienced by these three categories of corridor highway users (local auto travelers, intercity auto travelers, and truckers) of $10 per hour is used, the collective value of their travel time savings would amount to $0.3-1.1 million annually.

Table 5-9 also presents estimates of potential reductions in flights and delays at Boston and New York-area airports that could result from the diversion of air travelers to improved rail service. These are derived by assuming that total commercial aircraft operations during the year 2010 at Boston's Logan Airport and at each of the three major New York-area airports (Kennedy, LaGuardia, and Newark) are reduced from their forecast levels by the same proportions as are the numbers of passengers using each airport. Further, one-half of this reduction is assumed to occur during morning and evening peak travel periods, the hours when these airports are most congested. In turn, total hours of passenger delay anticipated to occur at each of these airports are assumed to be reduced according to the observed exponential relationship between peak-period air traffic volumes and resulting delays.

As Table 5-9 shows, the potential time savings to users of Boston and New York airports are significant, particularly when compared to those estimated for corridor highway travelers. These potential savings range from 0.3-0.7 million hours annually under Program 2, to as much as 1.0 million hours each year for the substantial diversion of air travelers to rail anticipated under the most extensive improvement program (Program 5). Valued at the approximately $30 hourly rate implicit in the models used to forecast air travelers' potential diversion to other modes, these time savings to corridor airport users could range from $9 million to nearly $30 million annually over the array of improvement programs considered. (The $30 hourly figure for time savings experienced by air travelers is consistent with that recommended by the Federal Aviation Administration for use in evaluating projects that reduce air travel time; see Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs, FAA-APO-89-10, June 1989.)

Despite their potential magnitude, the extent to which these potential time savings to users of Boston and New York-area airports will actually be achieved is uncertain. This is because it is not known how the scheduling decisions of shuttle air service operators would respond to reductions in travel volumes of the magnitude expected to result from implementing high-speed rail service in the corridor. The hourly schedules of air shuttle operations have evolved largely in response to business travelers' demands for the availability of frequent scheduled service, particularly during peak morning and evening travel periods. Thus it is possible that a significant reduction in the frequency of peak-period Boston-New York air service might not result even if the availability of high-speed rail service diverted significant numbers of former air travelers.

Further, insofar as a reduction in the frequency of service actually occurs, it produces a partially offsetting increase in "schedule delay" suffered by air travelers. This occurs because reduced flight frequencies increase the difference between air travelers' desired departure times (determined by the scheduling of activities in connection with which they are traveling) and the scheduled departure closest to that time on which a seat is obtainable. As a result of these uncertainties, the estimates of time savings reported in Table 5-9 must be regarded as the maximum benefits likely to accrue to corridor airport users as a result of implementing high-speed rail service.

5.4.2 Potential Financial Impact of High-Speed Service on Amtrak

Table 5-10 reports estimates of the potential financial impact on Amtrak operations from introducing high-speed service in the Boston-New York portion of the Northeast Corridor. As it shows, the forecasts of ridership developed in this study also imply significant increases in passenger ticket revenues collected in this section of the corridor, with passenger revenues ranging from slightly under $300 million to nearly $400 million annually (in 1990 dollars), depending on the running time reductions actually realized from the improvement program and the corresponding increase in ridership.

At the same time, however, Amtrak would incur substantial additional costs to operate the high-speed trains and more frequent conventional train service north of New York. Based on unit operating expenses (per train-mile) for current Northeast Corridor Metroliner and conventional service, together with estimates of the number of additional train-miles required to operate the improved service, total Amtrak operating expenses for Boston-New York

TABLE 5-10. ESTIMATED IMPACT OF IMPROVED BOSTON-NEW YORK RAIL SERVICE ON YEAR 2010 AMTRAK PASSENGER REVENUES AND OPERATING EXPENSES (MILLIONS OF 1991 DOLLARS PER YEAR)

Measure	Program 2	Program 3	Program 4	Program 5
Passenger Revenue	$294 - 313	$317 - 336	$340 - 356	$362 - 384
Operating Expenses*	$258	$220	$220	$216
Net Operating Income	$36 - 55	$97 - 116	$120 - 136	$146 - 168

* Includes estimated expenses for train operations, maintenance of rolling stock, and maintenance of way and stations.

Source: Passenger revenue calculated from ridership forecasts and fare estimates reported in text. Operating expenses estimated from AMTRAK unit operating expenses for current Northeast Corridor service.

service would be nearly $260 million annually for the diesel-electric service provided under Program 2, and somewhat lower (about $220 million) with a fully electrified line (Programs 2, 3, 4, and 5) (again measured in 1990 dollars). These figures include estimated additional costs for train operations, maintenance of rolling stock, and operation and maintenance of way and stations in the Boston-New York section of the corridor.

On balance, Amtrak could realize a net operating surplus for the improved Boston-New York service ranging from as little as $36 million to as much as $168 million, with the higher figures corresponding to more ambitious corridor improvement programs. The latter range would represent a significant increase in the operating surplus currently earned by Amtrak on its Northeast Corridor operations. This was estimated to be approximately $100 million during its most recent fiscal year, but by far the largest part of that amount appears to result from New York-Washington operations, with the Boston-New York segment apparently running near the breakeven point.

It is important to recall, however, that the travel time reductions estimated to result in these increasing operating surpluses also require significantly larger capital investments, against which these projected contributions to Amtrak's financial situation should be weighed. These investments include not only those required to complete the rehabilitation and improvement projects detailed in this report, but also the outlays necessary to acquire sufficient additional equipment to support higher frequency service than is presently operated between Boston and New York.

5.5 SUMMARY OF POTENTIAL BENEFITS

Table 5-11 summarizes the estimated benefits of investments in improved rail service between Boston and New York. As it indicates, the estimated annual benefits from travel time savings (to both intercity and commuter rail riders), economic benefits to travelers induced to switch to rail travel, and reductions in highway and airport congestion range from $86 to $132 million for Program 2. As a result of substantial increases in each of these benefit categories, their total is anticipated to rise to the range of $141-193 million with electrification (Program 3), and to the $165-216 million range with the further travel time reductions resulting from the curve realignments included in Program 4. Under the Shore Line bypass option (Program 5), economic benefits to new Amtrak riders and time savings from reduced highway and airport congestion would each rise considerably, and in combination with travel time savings to Amtrak passengers could produce total annual benefits in the range of $184-238 million.

TABLE 5-11. POTENTIAL ANNUAL BENEFITS FROM RAIL IMPROVEMENT PROGRAMS (MILLIONS OF 1991 DOLLARS PER YEAR)

	Increase in Measure versus Program 1:			
Benefit Measure	Program 2	Program 3	Program 4	Program 5
Travel Time Savings	$59-89	$88-121	$98-130	$103-135
Benefits to New AMTRAK Riders	$18-23	$40-48	$53-60	$63-74
Time Savings from Reduced Congestion	$9-20	$13-24	$14-26	$18-29
Total Annual Benefits	$86-132	$141-193	$165-216	$184-238

6. CONCLUSIONS AND OBSERVATIONS

6.1 CONCLUSIONS

A major rehabilitation effort is a necessary part of any program to improve commuter and intercity rail passenger services between New York and Boston. An investment estimated at $1.1 billion is required to address safety concerns and replace fixed plant which has completed or exceeded normal service life. Most of the rehabilitation program addresses system elements associated with commuter as well as intercity rail services.

Additional system improvements, implemented in conjunction with system rehabilitation, can reduce trip time dramatically. Travel time between Boston and New York potentially can be reduced to between 3 and 2½ hours--possibly less--depending on the magnitude of the capital investment made and the rolling stock selected.

Several types of benefits, both time savings and economic, are summarized in Table 6-1. Large reductions in travel time would be expected to increase Amtrak ridership on the route between New York and Boston substantially. Compared to the present value of approximately 2.3 million passengers per year, and projections for 2010 of 3.4 million passengers without any improvements, annual ridership is estimated to grow as much as 5.5 million for a 2½-hour trip time. Approximately 80% of the new passengers would otherwise travel by air, with about 20% diverted from highways. Time savings for passengers would be approximately 5.8 million hours annually for commuters and from 3 million to 5 million hours for intercity passengers. The economic value of these time savings could range from $100 million to more than $200 million per year. Amtrak's increase in net revenue would be in the range of $36 million to $168 million (in 1991 dollars).

The estimated cost of alternative programs to improve trip time would be from $1.6 billion (for a trip time of approximately 3 hours) to $3.6 billion (2½ hours or less) for fixed plant investment alone, including $1.1 billion for rehabilitation (1991 dollars). Funding permitting, the improvements could be implemented within a period of 8 to 10 years; service improvements should begin to be apparent within 5 to 6 years. In terms of a decade-long speed-improvement effort, the average annual expenditure required would be from $50 million to $250 million. The necessary additional rolling stock, which would be acquired over several years as fixed-plant improvements are implemented, would cost in the range of $300 million to $400 million.

TABLE 6-1. SUMMARY OF BENEFITS

PROGRAM:	2. BASIC SYSTEM IMPROVEMENTS	3. BASIC SYSTEM IMPROVEMENTS AND ELECTRIFICATION	4. ALL SYSTEM IMPROVEMENTS AND ELECT.	5. SHORE LINE BYPASS
ANNUAL INTERCITY RIDERSHIP* (MILLIONS)	4.7	5.0	5.3	5.6
NEW RIDERS DIVERTED FROM: AIR: (MILLIONS)	1.6	1.9	2.1	2.4
HIGHWAY:	.5	.5	.6	.6
ANNUAL TIME SAVINGS (MILLIONS OF HOURS) COMMUTERS:	5.0	5.8	5.8	5.8
INTERCITY:	2.6	4.1	4.7	5.1
ECONOMIC VALUE OF SAVINGS ($ MILLION/YEAR) TRAVEL TIME:	$59-89 M	$88-121 M	$98-130	$103-135 M
BENEFIT TO NEW RIDERS:	18-23	40-48	53-60	63-74
USERS OF OTHER MODES:	9-20	13-24	14-26	18-29
TOTAL:	86-112	141-193	184-238	184-238
POTENTIAL CHANGE IN AMTRAK ANNUAL NET OPERATING INCOME (MILLIONS OF DOLLARS)	$36 - 55 M	$97 - 116 M	$123 - 136 M	$146 - 168 M

* BASELINE: 2.3 million riders in 1989; 3.4 estimated in 2010 with no improvements in trip time or frequency; 3.8 with hourly express and conventional departures but no change in trip time.

6.2 OBSERVATIONS

6.2.1 Rolling Stock Considerations

Selection of appropriate rolling stock will be an inherent and critical element of any improvement program. These decisions depend on many factors outside the scope of this study, including operating and maintenance costs, compatibility with Amtrak operations and facilities, and passenger comfort aspects.

Suitability to run-through service from Boston to Washington is particularly important. The level of train movements now occurring in and out of Pennsylvania Station and through the East River Tunnel has already reached system capacity at peak hours. Turning of trains in that station will be less and less a viable option. In addition, a substantial fraction of current Amtrak passengers between Boston and New York actually have origins or destinations south of New York. They would benefit from the improvements addressed in this study only for run-through service.

Motive Power: Table 4-10 showed that running time for a given program of improvements is relatively insensitive to the choice of motive power, so long as a sufficient power-to-weight ratio is achieved. The largest single effect is associated with elimination of the 10-minute engine change in New Haven, either by Boston-New Haven electrification so that electric power is used for the entire route, or by a use of gas turbine locomotion which can also operate on small traction motors powered by a third-rail in the East River tunnels. (The actual saving is less than 9 minutes, due to the regular 1¼-min. dwell time.)

Variations in train power-to-weight ratio are relatively unimportant once values greater than 10-15 HP/ton are obtained, unless speeds above 130 MPH are possible. In that range, high power-to-weight is essential. TPC computations indicate that an appropriately-geared AEM-7 electric locomotive, nominally 7000 HP, pulling six Amcoaches, has sufficient power to reach only 137 MPH; adding a second unit yields a top speed of 147 MPH.

Gas turbine powered trains--when equipped to operate off third-rail electric power--provide an alternative way to avoid the 9-minute delay for the engine change in New Haven. However, several issues arise in considering the role of turbine power in the Boston-New York corridor. The existing example now in use by Amtrak represents 15-year-old technology, upgraded in 1986 and 1987. The power units provide only 2280 horsepower, and would have relatively weak performance on an improved Northeast Corridor. Currently proposed turbine trains--with a twin-turbine power unit at each end--would provide approximately 5800 HP. If successfully constructed, these units could yield a running time substantially less than the existing turbine train.

Even a higher power turbine train would have to address several concerns. Other than the low power, several limitations relevant to Corridor operations have been noted in connection with existing Empire Service turbine trains. In addition to vulnerability of third-rail power pickup shoes to damage, low traction power when operating as an electric train can limit speed and reliability for moves through the East River tunnels; current equipment is moved by a separate electric locomotive. Also, the reliability of a new generation of turbo trains, with a total of four turbines per trainset, remains a subject of uncertainty.

Operationally, Amtrak considers run-through operation from Boston to Washington to be very desirable, based on markets served, rationalization of the fleet, and maximization of platform and tunnel capacity at Pennsylvania Station. It does not appear that turbine trains in the configurations that have been proposed would be suitable for service south of New York, since longer, high-power trains are needed on that route. However, turning trains at New York is likely to be increasingly unacceptable at peak hours.

Another contrast between electrification and turbine power is that under electrification, all trains could avoid the New Haven engine change and operate through-service between Boston and Washington, whereas benefits from turbines are proportionate to the size of the fleet acquired. Since conventional (nonexpress) service is expected to carry 40% to 50% of intercity ridership, benefits would be significantly constrained if that service remained diesel-electric, operated in parallel with turbo express trains. The ridership values that were shown in Table 4-11 for turbine trains apply only if the entire fleet is turbine-powered.

It is claimed that an improved turbine train could be available in 2 to 3 years. Since electrification is not likely to be fully in place until several years beyond that time, it would be possible to consider interim use of a turbo prototype to gain practical experience with this technology to assure that future choices are soundly based. Several beneficial results would be obtained. The immediate gain of nearly 9 minutes at New Haven would help to offset the impact of delays likely to occur due to construction of rehabilitation and system improvement projects. Further, this would permit evaluation of advanced turbine operating reliability and maintenance costs, as well as actual performance on the corridor. Regardless of NEC electrification, there are routes such as Hartford/Springfield-NYC and Albany-NYC, possibly joined into a single run, for which a fast train with effective third-rail capability, if that can be achieved, might be well suited.

Several high-speed, light-weight electric trainsets have been developed in Europe during the last decade. Advanced suspension systems, as well as high power-to-weight ratios, make these promising candidates for use in the Corridor, assuming that maintenance characteristics and operating cost are found acceptable. In addition to offering a high level of passenger comfort, they typically provide lower axle loadings, which reduces track maintenance requirements. Trial use of this equipment on currently electrified portions of the corridor would also be a logical step in developing long-term fleet acquisition plans.

Tilt Suspensions. Under the assumption of 6-inch superelevation and 6-inch unbalance for nontilting coaches, use of a tilting suspension to permit 8-inch unbalance increases the speed limit for a given curve by only 8%. The TPC computations show that a tilting suspension typically reduces Boston-New York travel time by about 5 minutes, but only for a track structure and signal system which allows speeds up to 130 MPH (Programs 2 and 3); at the 110 MPH limit for Program 1 operation at the higher speeds (greater than 110 MPH) made possible by tilting can seldom be used so that no significant gain is realized.

Further, the benefits of tilting are based on the assumption that 8-inch unbalance, with 6 inches of superelevation, is acceptable for most curves between Boston and New York. It is likely that this assumption will not be found valid for some curves, due to limitations on the amount of transition spiral available for entering and exiting the curve. Detailed testing and analysis will be necessary to establish the true magnitude of tilt benefits. It is possible that the projected time savings would be reduced somewhat by such a process.

The potential role of tilt suspensions also depends in part on the resolution of technical uncertainties. Tilt mechanisms are quite complex, and have not been used extensively in the U.S. There is a potential for excessive maintenance costs. Further, reliability is critical: if the tilting mechanism is nonoperative on only one car, the train will have to observe nontilt speed limits, and the investment in tilt technology will yield no benefit for that trip. Just as for turbine trains, considerable testing and trial operation would be necessary to determine the value and role of tilt-trains in the Corridor.

6.2.2 Commuter Rail Impacts

Many possible improvement projects would be in segments heavily used by commuter rail passengers. These commuters would, in many cases, experience long-term service improvements comparable to those for intercity riders, as well as increased system capacity. Estimated cumulative time savings for commuters range are of the order of 5 million hours annually.

On the other hand, even with carefully planned and coordinated phasing of projects, performance of major infrastructure improvement tasks in the presence of heavy commuter rail traffic will inevitably generate delays and service interruptions during construction. In addition, operation of more intercity trains at higher speeds will impose on the commuter railroads a variety of new constraints, costs and requirements concerning track maintenance, compatibility of rolling stock, and dispatching.

Capacity limitations (discussed below) at Pennsylvania Station and the East River Tunnels imply that increased Amtrak service would significantly affect Long Island Rail Road commuter operations which share those facilities.

6.2.3 Future System Capacity

This study did not explicitly examine Corridor capacity. Program 2 improvements, such as Shell and Harold flyovers, restoration of a fourth track from New Haven to Norwalk, and additional tracks in the Boston area, capacity generally appears to be adequate to carry anticipated commuter and intercity traffic through the 2010 time period. However, at Pennsylvania Station and the East River Tunnels, the system as currently operated is already at capacity during peak hours. Means of ameliorating this situation are being explored by MTA and Amtrak, but it appears that operational improvements beyond the scope of this study will be required to avoid potentially-severe impacts, particularly on commuter operations, from any increase in intercity traffic.

There are other locations where the system will be near or at its limit, and a concerted and integrated effort will be required to maximize Corridor capacity for all services. Detailed future analyses could show other problem areas.

6.2.4 Financial Capacity for Implementation of Improvements

Allocation of funding responsibility for NEC improvements would depend on many considerations and is not within the scope of this study. However, some comments can be made concerning the financial capacity of involved parties to support improvements. During the period 1970-1990, public investment in the Boston-New York portion of the Corridor totaled approximately $1.9 billion--an average of about $100 million/year--of which more than $1.1 billion was provided through the Northeast Corridor Improvement Program. The remainder was UMTA funding and matching funds from states or transit authorities. For projects identified in this study $120 million is currently available for rehabilitation (almost all from UMTA, MTA, NYDOT, and CDOT), and $119 million for system improvements, all from the FY91 appropriation for Amtrak. However, this history is not a useful guide for the future. Financial constraints have tightened sharply in the last year for all agencies.

Some of the Amtrak projects, such as trackwork and fixed bridge improvements, may be addressed over time as part of normal maintenance and capital programs. However, for most of the identified improvement projects Amtrak has no internal funding capability and is dependent on directly appropriated funds, such as the $119 million received in FY91 for the Boston-New York portion of the Corridor. The Amtrak request for FY92 includes $180 million for projects contained in Programs 1-3, but this is not reflected in the Administration's 1992 budget as submitted to Congress.

Approximately one-half of the Rehabilitation and Basic System Improvements programs would be directed at facilities owned by Connecticut DOT. The current CDOT 10-year capital plan, which includes rail service, is based on anticipated funding from UMTA, state revenues, and transportation bonds. The plan indicates that only about one-third of the funding associated with Program 1 will be available over the next 10 years, and even less of the Program 2 funding.

6.2.5 Implementation Considerations

Delineation of a Specific Program: Each program defined in this study, or any variant which might be developed, is more than the sum of the projects comprising it. Some projects have direct logistic connections with one another, as for trackwork, signaling and electrification. Others are linked operationally, such as Stamford Platforms and Shell Interlocking, or are connected through the need to minimize disruption of traffic. Quite generally, the overall system to which each project is to contribute should be defined before detailed design of that project is completed. System definition would include plans for other projects, future operating speeds, dispatching and other operational strategies, level of traffic, type of rolling stock to be used, electrification details, and many other factors. Any attempt to upgrade the Corridor one project at a time, without clear definition of characteristics such as these, is very likely to be plagued with inefficiencies and unsatisfactory results. Hence, if any major investment is to be made in the Corridor, it is most important that it include a strong and explicit commitment to a well-defined program.

Implementing Agencies: As a means of identifying the organizations likely to be most heavily involved in any improvement program, the expenditures in each improvement program are shown in Table 6-1 categorized by right-of-way owner. (Electrification costs in Massachusetts, where MBTA is the owner, are included under Amtrak, since Amtrak would be responsible for the project.)

Table 6-2 makes clear that Amtrak and CDOT are the principal owning agencies to be considered, with MTA potentially involved in the safety project at Penn Station and the East River Tunnels. Metro-North Commuter Railroad is responsible for all commuter operations, as well as dispatching and track maintenance, on the portion owned by CDOT; Amtrak plays a similar role in the Massachusetts portion of the Corridor, which is owned by MBTA. Thus, Amtrak, CDOT and MNCR would be the principal parties involved in implementation of any program.

TABLE 6-2. DISTRIBUTION OF PROGRAM COSTS BY OWNING AGENCY, IN MILLIONS OF 1991 DOLLARS

PROGRAM:	1	2	3	4	5
AMTRAK					
Penn Stn/Tunnels:[1]	$366 M	$366 M	$366 M	$366 M	$366 M
Electrification:[2]			445	445	445
All Other Projects:	146	306	318	976	1827
Total:	512	672	1129	1787	2638
CDOT	538	704	717	772	772
MTA					
Harold/Shell I/L:		95	95	95	95
All Other Projects:	25	33	33	33	33
MBTA[2]	4	54	54	61	61
TOTAL:	1079	1558	2028	2748	3599

1. Shared with MTA/LIRR
2. Electrification in MBTA-owned territory included under Amtrak

Process: The difficulty of bringing about major improvements on operating rail systems was made all too clear in the Northeast Corridor Improvement Program of the 1970s and '80s. In addition to the inherent complexity of the engineering task, organization and management of the work is particularly challenging. Generally, the owner/operator of that portion of the railroad being upgraded is in the best position to serve as program manager. However, the NEC is a multipurpose facility, drawing substantially on public funds, and the management process must be one that fully reflects the interests of all parties, including the society at large. The development of a process which is efficient but inclusive and truly representative of overall societal interests warrants high priority in any implementation effort.

An institutional and procedural framework would be needed within which all parties--railroads, government agencies at all levels, and transportation authorities--work in a highly coordinated and cooperative manner to realize a commonly accepted vision of integrated Northeast Corridor rail services. Essential to achieving this framework will be equitable distribution of not only capital costs, but future operating and maintenance expenses as well. Given the number of organizations involved, their differing responsibilities, functions and perspectives, and the financial constraints facing all of them, this could be the most daunting challenge to improving NEC performance.

Sequencing and Priority of Projects: The logical sequence charts shown in Figures 4-2 through 4-5 are idealized in that they assume no funding constraints and do not incorporate detailed analysis of construction period impacts on traffic. Given the extensive design work required in most cases, and the inherent lengthy construction period required, most projects are shown as being initiated at the outset of the program of which they are a part. Actual construction schedules would be strongly affected not only by availability of funds, but also by the need to implement each project in a manner which minimizes disruption of current services, including balancing of delays from projects located near to one another. To the degree that such considerations do not dominate, however, some major projects that offer immediate significant benefits appear to warrant priority in implementation if a program including them is to be undertaken. These include the following:

- o Improvements at the New Haven Terminal, which offer immediate trip time savings of at least 5 minutes, improved operations, and reduced terminal area maintenance costs;

- o Shell Interlocking, which will be a lengthy project, and is a significant source of delays in periods of peak traffic;

- o Stamford Island Platforms, which offer major direct benefits to commuter operations and are closely linked to congestion at Shell Interlocking;

- o Electrification, which would provide an immediate 9-minute time savings and facilitate improved Boston-Washington run-through service, as well as permitting trial service of advanced technology electric trainsets; and

- o Peck Bridge replacement, which will require approximately 7 years for completion, and which is now dependent on a temporary modification for continued safe and reliable use.

All of these projects are now being addressed, each (with the exception of Stamford) having some degree of initial funding.

6.2.6 Accessibility of Rail Stations

The Americans with Disabilities Act of 1990 (ADA) established specific accessibility standards for physically handicapped passengers for intercity and commuter rail stations and passenger cars. With regard to stations, Section 242 in the Act mandates the following:

- All existing intercity rail stations shall be accessible within 20 years (i.e., by 2010);

- All new intercity and commuter rail stations shall be accessible, and all alterations to existing stations must include accessible features "to the maximum extent feasible"; and

- All existing commuter rail stations designated in a public process as 'key' shall be accessible within 3 years unless the only means of doing so would be to raise the entire passenger platform, in which case 20 years is allowed.

A number of the existing NEC stations between Boston and New York are either already accessible or plans are being developed to make them accessible. One major exception to this is Route 128 station, which is lacking both high-level platforms and an accessible passage between the two platforms. Plans have been developed for joint MBTA-Amtrak project to construct high-level platforms, initially motivated by the resulting significant reduction in station dwell time. Programs 2-5 include high-level platforms at this station.

The cost estimates in this study do not incorporate the requirements of ADA, which is basically a separate topic. This Act establishes requirements that must be met regardless of whether any of the projects in this report are approved and implemented, and each railroad will have to concern itself with ADA for all stations; it is not unique to the NEC. The Station Improvements project in this study includes an estimate for provision of high-level platforms and pedestrian overpasses at those Amtrak stations between Boston and New York not currently so-equipped. However, due to the special nature of the requirements of this act, it is otherwise considered beyond the general scope of the study, particularly insofar as commuter stations and rolling stock are concerned.

6.3 UNCERTAINTIES AND ISSUES TO BE RESOLVED

Achievement of these projected gains in trip time for any program of fixed plant investment would require significant complementary actions, long-term decisions, and resolution of key uncertainties and issues. Topics which would need to be addressed are discussed in the remainder of this section.

6.3.1 Refinement of Cost Estimates and Detailed Planning

The analysis presented in this document can provide the technical foundation for decisions concerning future investment in the Corridor. However, only a few of the prior and concurrent studies from which cost estimates were drawn were based on detailed designs and analysis. If a decision is made to implement any one of the Programs described here, many of the projects would require substantial further definition of scope and approach so that engineering estimates of cost and schedule presented here can be refined and validated. This planning is now proceeding for projects which have already received partial funding, but a much more comprehensive effort would be needed to develop plans and schedules which fully incorporate consideration of project benefits, availability of funds and other resources, impacts on traffic, and the overall program objectives and schedule.

6.3.2 Characterization and Evaluation of Alternative Rolling Stock

Trip time, operating costs, and passenger comfort are significantly affected by the characteristics of the coaches and power units used. Selection of rolling stock must be based upon the overall goals of the specific improvement program (including projected maximum operating speed), the operating scenarios envisioned, the spectrum of equipment available from the marketplace, and thorough analysis of life-cycle costs. Given the typically long operating life of railroad rolling stock, the importance of standardizing equipment, and the relatively large fleet which might be required, it is particularly important that a sound decision be made.

Several types of equipment may be found necessary to provide the various services to be offered: premium express, conventional multistop, off-corridor routes to Hartford and Albany, etc. A variety of advanced high-speed passenger rail equipment developed in Europe--including tilt-body suspensions and gas turbine locomotion--is now being offered by several firms. The suitability and attractiveness of these trainsets can be determined only through thorough evaluation based on extensive use in realistic circumstances. It will be particularly important to determine maintenance and reliability characteristics in the context of corridor operations and procedures.

6.3.3 Safety and Passenger Comfort Standards for High-Speed Operation

The projected higher speeds in all programs are based on the assumption that the FRA and Amtrak will conduct or review necessary testing and analysis to confirm the acceptability of higher speeds on curves, and to define standards for rolling stock and inspection and maintenance procedures necessary for safe and comfortable operation at those speeds.

6.3.4 Operating and Maintenance Costs

The assessment of fixed-plant capital costs contained in this study is only a first step in identifying the financial implications of providing improved rail service between Boston and New York. Detailed analysis of long-term operating and maintenance costs for alternative improvement programs and rolling stock choices is desirable to support decisionmaking and planning, and to address allocation of funding responsibilities.

6.3.5 System Capacity

Pennsylvania Station and the East River Tunnels already pose a capacity problem with regard to commuter service at peak hours. There are other locations where the system will be near or at its limit if Corridor improvements are implemented. Sophisticated computer-based simulation tools will be required to analyze these situations in sufficient depth to identify problems and to develop and evaluate alternative resolutions.

6.3.6 Ridership Projections and Benefit Analysis

It was not within the scope of this study to undertake the data collection and modeling effort which would be required to support a more precise projection of potential ridership for various cases of trip time, fares, and operating scenarios. However, information of this nature is highly desirable in refining decisions concerning Corridor improvements and rolling stock acquisition. This type of information is also needed to assess more accurately a broad range of benefits which might be expected to accrue to service improvements, including impacts on airport and highway congestion, energy use and economic development.

6.3.7 Impacts on Freight Service

The study revealed significant concerns on the part of freight service operators on the Corridor as the future of rail freight transportation, including possible adverse impacts of some of the projects being considered. A study of the freight railroad impacts and benefits associated with Corridor improvements appears to be appropriate.

APPENDIX A

PROFILES OF CANDIDATE NEC IMPROVEMENT PROJECTS

Potential Funding Sources and Implementation Roles: The project profiles indicate agencies which might potentially participate in funding the project in question. This entry is merely to suggest possible sources, and does not imply either the agreement of those agencies or that they have any obligation in that regard. Similarly, the listing of roles and responsibilities in implementation activities is provided to indicate a logical possibility; other arrangements might be developed.

Benefits and Beneficiaries: The nature and qualitative importance of each project is indicated for both intercity passengers and commuters. The degree of benefit is a judgement which cannot be made rigorously quantitative. Factors which go into this assessment include impacts on speed, capacity, traffic conflicts and operational flexibility, as well as the views expressed by the involved organizations. The profiles include a judgement as to the relative degree to which commuters and intercity passengers benefit. This represents a qualitative "multiplication" of the level of benefit by the number of beneficiaries, based on commuter and intercity traffic at the location of the improvement. In some cases, the result is clear; there are no commuters in that location, or they receive no benefit. For other projects, the conclusion is more ambiguous, and these characterizations should be used only where this qualitative approach is consistent with the intended purpose.

Issues and Uncertainties: Most of the profiles include an indication of current uncertainties or issues associated with the project in question. Entries made there are those which have emerged clearly in the course of the study, but should not be taken as complete. Funding, which is both an uncertainty and an issue for almost all projects, is not included in this element of the profile.

Abbreviations Used in this Appendix:

CDOT	Connecticut Department of Transportation
CR	Conrail
FRA	Federal Railroad Administration
LIRR	Long Island Rail Road
MBTA	Massachusetts Bay Transportation Authority
MNCR	Metro-North Commuter Railroad
MTA	Metropolitan Transportation Authority
NEC	Northeast Corridor (New York-Boston portion)
NJT	New Jersey Transit
P&W	Providence and Worcester Railroad
RIDOT	Rhode Island Department of Transportation
ROW	Right-of-Way
UMTA	Urban Mass Transportation Administration

The project profiles contained in this Appendix provide a summary of the problems addressed and the approaches which might be taken in bringing the NEC to a state of good repair and improving intercity trip time and service. The appendix includes all major projects (some of a multiple or geographically distributed nature) which have been identified in the course of the VNTSC study. Selection of specific projects for inclusion in overall NEC improvement programs is described in Section 3 of the full study report; inclusion in this appendix does not in itself represent a recommendation for implementation or incorporation into any program.

With a few exceptions, no new design or analysis of projects has been undertaken in the VNTSC study; the information presented here is based on previous reports and studies, other information provided by relevant parties, and discussions with knowledgeable individuals. Some of the candidate projects have been designed or examined by railroads or public agencies recently and in great detail; others have been little studied for many years. Thus, the level of detail necessarily varies considerably among the projects, as may the precision of the data shown. In a few cases the feasibility, practicality, and value of identified projects would have to be confirmed by further studies prior to initiation of detailed design and implementation.

Cost Methodology: **All estimates are in terms of 1991 dollars.** In most cases other than work already well into design or initial construction, project scope is not well defined, precluding detailed design and staging of construction. Hence, precise cost estimates are not possible.

Projects for which substantive cost estimates were available were simply reviewed for completeness and converted (if necessary) to constant 1991 dollars. For other projects, which included most of those identified, independent estimates were prepared for VNTSC by Parsons Brinckerhoff based on a conceptual level of detail. A contingency factor of 30% was applied to the base estimate in each case to compute total construction cost. An allowance of 10% for engineering and design, 8% for construction management, and 5% for agency and administrative cost (including flagging protection) was added to arrive at total estimated project cost. In each estimate, the work was broken down into earthwork, structures, trackwork, catenary, signals, and allowance for maintenance of traffic as appropriate. Most such estimates are based on very limited site-specific information and are subject to further detailed investigation and confirmation; however, they are believed to be sufficient in almost all cases to support budget formulation.

Funding and implementation information presented in the project profiles is intended merely to enhance the reader's understanding of the project by suggesting a likely course of events. It represents neither a recommendation nor, in most cases, established agreements. Except where noted, no funds have been appropriated for these projects; some are contained in the long-term capital expenditure plans of the railroads or agencies.

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Project: Penn Station/Tunnel

Project Full Name: Safety Enhancements at Penn Station and East River Tunnels

Location: Penn Station and East River Tunnels (MP 0 - E2)

Safety Considerations: Tunnel and station improvements will significantly improve safety; many are required by Code in support of the Emergency Response Plan.

Revenue Trains per Day:	Intercity:	34 (NYC east)
	Commuter:	397 (LIRR) More than 600 LIRR and NJT, including deadhead
	Freight:	0

Rehabilitation/Speed Improvement: The tunnel and station enhancements for the Emergency Response Plan are required for safety. Capacity and speed improvements are also needed.

Description of the Problem: The four East River Tunnels, built in 1906, and Pennsylvania Station do not comply with numerous current regulations and safety standards applicable in New York City or provisions of the National Fire Codes. An operational Emergency Response Plan which has been developed has highlighted the need for substantial infrastructure modifications.

In addition, station capacity is constrained by platform width and accessibility (stairways/escalators/elevators); interlockings at the throats of the tunnels restrict movements of trains in and out of the station.

Capacity limitations and station physical constraints (platform access, rolling stock storage) particularly affect LIRR and NJT services. There is a lesser impact on intercity service since Amtrak owns Penn Station and has nonexclusive rights to 12 platform tracks.

Proposed Solution(s): Tunnels: Installation of better emergency signage, walkways, and lighting is underway; additional needs are construction of improved ventilation, electrical power systems, and other safety enhancements dictated by the Code and recommended in the report "Application of the Emergency Response Plan Study" (Schirmer Engineering Corp., 1990).

Penn Station: Improvements -- particularly those affecting overall capacity and commuter service -- are being addressed under an MTA study effort. There are also substantial required safety enhancements.

Current Plans, Status, and Activity: Some emergency tunnel improvements are underway; most are unfunded at this time; operational improvements are being evaluated by the affected parties. LIRR, NJT and Amtrak are each undertaking studies and improvement programs directed at fire and life safety within Penn Station. Particular concerns are evacuation capability from platform level to the street or other point of safe refuge and asbestos removal. Amtrak has recently awarded to Linpro a 9-month conceptual design and master planning effort which will unify the at-present separate undertakings.

Project Description: Participation in tunnel safety improvements and overall operational changes.

Brief History: Penn Station opened in 1910. For many years a single entity, the Pennsylvania Railroad, owned the station and provided all services -- intercity and commuter. The evolution to a primarily commuter function, with extreme peaks of traffic in morning and late afternoon, involving two commuter railroads as well as Amtrak, has greatly complicated matters. The original station was demolished in 1965 to permit the Madison Square Garden and Penn Plaza overbuild. Recently, the West Side Yard has been constructed to reduce the deadhead moves to and from Jamaica by providing additional storage, and in April 1991 Amtrak completed the Empire Connection so that all Amtrak trains serving New York now use Penn Station; previously, service to the north and west (Albany and beyond) orginated at Grand Central Terminal. All dispatching has been by Amtrak personnel, but a recent Joint Facility Agreement provides for sharing that responsibility with LIRR.

ROW Owner: Amtrak

ROW Maintenance: Amtrak

Dispatching Responsibility: Amtrak, LIRR

Train Operators: Amtrak, LIRR, NJT

Project Implementation:

(Potential) Funding Agencies/Sources: Under a Joint Venture Agreement, improvements are being funded jointly by Amtrak and LIRR. A similar agreement is pending with NJT. Other sources of funding are possible and may be required.

Managing Organization: Amtrak

Performing Organization: Contractor

Sequencing Considerations:

Other Construction/Logistic Considerations:

Construction-Period Operational Impacts:

Affected Parties: Amtrak, LIRR, NJT

Purpose or Intended Benefits:

Intercity Service: Enhanced safety including compliance with safety standards; increased capacity and reduced delays.

Commuter Service: Enhanced safety; increased capacity and reduced delays.

Principal Beneficiary: Safety is highly important to both commuter and intercity service. On the basis of the very high level of LIRR traffic compared to Amtrak, LIRR is judged to be the primary beneficiary.

Uncertainties and Issues: It is not clear if any meaningful increases in basic system capacity can be achieved at Penn Station without embarking on very large civil projects (new tunnels, etc.) However, increased operation of run-through trains would open "slots" at platforms and in the tunnels. Operational improvements, including greater reliability on the entire system, could permit reduced dwell times for intercity trains, similarly increasing platform capacity. The existing limitations at Penn Station may define the boundaries on operations at the NYC end of the Northeast Corridor for the forseeable future. Since Amtrak owns the facilities in question, the primary burden of capacity constraints falls on commuter operations, principally the Long Island Rail Road.

Estimated Cost: Schirmer Engineering Corp. has developed preliminary cost estimates for Code stipulated safety enhancements for Penn Station and all tunnels, on a systemwide basis. An estimated $500 million is required to implement the improvements. Of this amount, approximately two thirds is required to achieve required emergency ventilation and other Emergency Response Plan improvements in the East River/Penn Station side of the complex.

Additional flow-related access/egress improvements are not yet developed to the point of cost estimates. A total budgetary estimate of $375 million is suggested for NY-Boston side improvements in the East River tunnels and Penn Station.

Ventilation	$245M
Other Emergency Response Plan Improvements	95M
Allowance for share of flow-related access/egress improvements	35M

Total Improvements, Penn Station/East River Tunnels	$375M

Project: Catenary Replacement

Project Full Name: Replacement of Catenary between New Haven and the Connecticut State Line, and Support Structures Rehabilitation on the Hell Gate Line

Location: New Haven to Connecticut/New York line (MP 72 - 26)
Shell Interlocking to Harold Interlocking (MP 19 - E4)

Safety Considerations: Not a major factor. Catenary failures could cause congested situations which reduce operational margin of safety.

Revenue Trains per Day: Intercity: max. 34
Commuter: max. 185
Freight: max. 5

Rehabilitation/Speed Improvement: Rehabilitation

Description of the Problem: The catenary between New Haven and the Connecticut-New York line is 75 to 80 years in age and overdue for replacement. Maintenance costs are rising sharply and reliability is becoming questionable. Speeds are inherently restricted to 90 MPH, and are further reduced by timetable special instruction at certain curves in particularly cold or hot weather. The State of New York is funding replacement on the New York portions of the New Haven line; CDOT will be able to fund replacement only very gradually based on current budgets.

Proposed Solution(s): Replacement of the catenary, designing the system for the maximum speed that geometry and other constraints allow.

Project Description: The replacement, based on the design developed for CDOT, is understood to be of the constant tension type with a design top speed of 100 mph for six raised pantographs. The MNCR design (for use in New York) is constant tension and is reported to have a design top speed of 100 mph or more. These figures are assumed to be based on multi-unit car operation with 8 to 12 pantographs in contact with the catenary wire for each train. The same designs would presumably allow substantially higher maximum speeds with good current collection when only one or two pantographs are employed, as would likely be the case for Amtrak's proposed high-speed NEC trains.

As a part of the design process, computer simulation of operation of Amtrak high-speed trains over the proposed catenary should be conducted to verify acceptable current collection. Amtrak operating speeds in this zone may exceed 100 mph only infrequently, and 130 mph would be the maximum requirement in portions of the Bridgeport to New Haven segment only. Accommodation of such requirements should not pose a major technical or cost problem.

The logistics of catenary replacement on an operating four-track railroad are difficult in any event. An additional complication in this case is that approximately one-third of the Connecticut portion of the New Haven Line currently uses a "floating beam" suspension. Replacement is likely to require that all four tracks be taken out of service, which would allow work to proceed only at night or on weekends. This substantially increases the expense of the project.

Summary of Status and Issues: MTA has contracted for the construction of a new catenary system for the New York portion from Woodlawn to Port Chester, and CDOT has separately contracted for design of new catenary in the Connecticut segment. While no further rehabilitation of the Hell Gate Line catenary itself is currently programmed, there is a need for repair of deteriorated support structures.

Current Plans, Status, and Activity: MNCR catenary in New York is now being replaced, based on an MNCR design. CDOT is developing a design for the Connecticut portion, but near-term implementation will depend on identification of funding not now available.

Amtrak has not developed a program for structural rehabilitation of the catenary support structures or the Hell Gate Line.

Coordination of the catenary replacement program among MNCR, CDOT and Amtrak will be important. The design process should be structured to assure that future requirements of all users will be addressed and met in the first instance without costly retrofit.

Brief History: Replacement of catenary in these zones was originally planned in NECIP, but was not undertaken for MNCR territory. The Hell Gate line was restrung during NECIP but the structural rehabilitation work was deferred.

ROW Owner: Amtrak, Hell Gate Line, MTA, New York portion of Shell-New Haven; CDOT, Connecticut portion of Shell-New Haven.

ROW Maintenance: MNCR (New Haven Line), Amtrak (Hell Gate Line)

Dispatching Responsibility: MNCR (New Haven Line), Amtrak (Hell Gate Line)

Train Operators: MNCR (New Haven Line), Amtrak, Conrail

Project Implementation:

(Potential) Funding Agencies/Sources: UMTA, CDOT, MTA (New Rochelle-CT state line only)

Managing Organization: CDOT/MNCR

Performing Organization: Contractor

Sequencing Considerations: Catenary replacement inherently requires that at least one track be out of service. The project must therefore proceed in small segments in order to prevent excessive disruption to traffic.

Other Construction/Logistic Considerations: The need to replace one small segment at a time implies a lengthy construction period. In some locations all four tracks will be out of service at once, necessitating night or weekend construction.

Construction-Period Operational Impacts: Significant delays to service are to be expected.

Affected Parties: MNCR, Amtrak, Conrail

Purpose or Intended Benefits:

Intercity Service: Replacement will directly improve service reliability and eliminate speed restrictions due to temperature extremes. In concert with other specific rehabilitation and speed improvement work, such as bridge improvements and increased superelevation, new catenary will make possible use of substantially higher speed limits.

Commuter Service: The principal benefit for commuter service will be improved service reliability and significantly reduced maintenance cost. Higher speeds will also be of value.

Principal Beneficiary: Improvements in reliability and speed are of high value to both users. On the basis of the much higher level of commuter rail traffic, commuter services are seen as the principal beneficiary.

Uncertainties and Issues: Assurance of the capability of MNCR and CDOT catenary to support 100-130 mph current collection with one-or-two-pantograph configurations. In addition, since intercity trains will generally be limited to the speed of express commuter trains, extensive coordination is required concerning catenary design and motive power plans in the next decade.

Estimated Cost: Catenary rehabilitation/replacement on the New Haven to Port Chester (CT/NY State Line) portion of the New Haven Line, including major yards and stations (but excluding the New Canaan Branch) is estimated to cost $350 million. Replacement of the Port Chester to New Rochelle catenary is estimated to cost $24 million, assuming this work represents 75% of the $32 million construction contract recently awarded for the full Port Chester-Woodlawn portion of the line. The Hell Gate Line catenary structure rehabilitation is estimated to cost $3 million.

Project: Peck Bridge Replacement

Project Full Name: Replacement of the Pequonnock River Railroad Bridge and Bridgeport Viaduct

Location: Immediately east of Bridgeport station (MP 55 - 56)

Safety Considerations: Reconstruction is required for continued safe operation

Revenue Trains per Day:

Intercity:	34	
Commuter:	78	(MNCR)
Freight:	2	

Rehabilitation/Speed Improvement: Rehabilitation

Description of the Problem: The 87-year old Peck Bridge and Bridgeport Viaduct structure has experienced substantial steel corrosion throughout its entire 2500-foot length. In addition, inherent deficiencies in the bridge foundation have resulted in movement requiring a major pier stabilization project to maintain safe use. The drawbridge is inoperable, and deterioration continues. CDOT pays demurrage to upstream users of the Pequonnock River to compensate for restricted river access.

Proposed Solution(s): Based on a 1988 MNCR/CDOT study, funded and sponsored by CDOT, it was concluded that rehabilitation is not practical and a new structure is required. The lowest cost solution was identified as replacement of the bridge on the current alignment, with improvements to horizontal curvature.

Project Description: Design, now in progress, calls for replacement of the existing rolling lift structure with a trunnion bridge and new viaduct structure which will maintain the current alignment and four-track configuration, and will permit higher marine and highway clearances. Temporary detour trackage will be constructed to maintain rail operations during the construction: speeds will be limited to 15 MPH during the 3 years of its operation. Final speed limit on the new bridge will be 45 MPH.

There have been suggestions that an alternative be considered: realignment incorporating a new fixed bridge closer to the mouth of the river, which would bypass the entire viaduct structure and eliminate Jenkins Curve, a 5 degree curve immediately southwest of the Bridgeport Station. A new station, further west, would be required in this concept, increasing cost but offering a better station location. This alignment would reduce travel time by approximately 3 minutes for trains not stopping at Bridgeport. However, a very approximate estimate suggests a cost in excess of $400 million, accompanied by potential problems in land acquisition and environmental impact review. Also, the required height of a fixed bridge would necessitate a fairly steep gradient. This alternative was considered but rejected early in the planning process for the bridge replacement project, and would presumably be attractive only in the context of a major urban renewal effort.

Current Plans, Status, and Activity: Design of the replacement is 90% complete. Twenty-three million has already been programmed; $105 (constant dollars) million in addition will be required for completion. Construction is planned for 1992-1998.

Brief History: A 1988 MNCR feasibility study, sponsored and funded by CDOT, included participation by numerous agencies. The problems were found to be so severe as to require bridge replacement. Although current traffic can be handled by three tracks, the decision was made that a four-track replacement was warranted to allow for future capacity needs.

ROW Owner: CDOT

ROW Maintenance: MNCR

Dispatching Responsibility: MNCR

Train Operators: MNCR, Amtrak, Conrail

Project Implementation:

(Potential) Funding Agencies/Sources: CDOT, UMTA

Managing Organization: CDOT/MNCR

Performing Organization: Contractor

Sequencing Considerations:

Other Construction/Logistic Considerations:

Construction-Period Operational Impacts: A temporary track around the bridge location will be required for up to 3 years of the construction period, imposing a 15 MPH speed limit on all trains and reducing the current four-track configuration to two tracks. Significant delays are anticipated.

Affected Parties: MNCR, Amtrak, Conrail

Purpose or Intended Benefits:

Intercity Service: The main benefit will be to assure safety. Some trip time improvement will result from the increase to 45 MPH operating speeds, compared to the current 30.

Commuter Service: The main benefit will be to assure safety. Some trip time improvement will result from an increase to 45 MPH operating speeds, compared to the current 30.

Principal Beneficiary: Both services benefit equally from the improved safety and reliability, with comparable traffic for each.

Uncertainties and Issues:

Estimated Cost: The project is estimated by CDOT to cost $128 million, including escalation to midpoint of construction (4th Quarter FY 1995), or $109 million in 1991 dollars. Monies already received place the unfunded portion at $86 M in 1991 dollars; when adjusted for inflation the remaining amount required is $106 million.

Project: Movable Bridges

Project Full Name: Replacement or rehabilitation of eight movable bridges: Pelham Bay, Cos Cob, Walk, Saga, Devon, Niantic, and Groton Bridges. (Peck is considered separately.)

Location: Pelham Bay (MP 15.73) on Amtrak's Hell Gate Line; Cos Cob (MP 29.91, Mianus River); Walk (MP 41.47, Norwalk River); Saga (MP 44.30, Saugatuck River); Devon (MP 60.44, Housatonic River); Niantic (MP 116.74, Niantic River); and Groton (MP 124.09 Thames River).

Safety Considerations: The long-term margin of safety at these bridges will continue to decline if required improvements are not carried out.

Revenue Trains per Day:	Intercity:	max. 34
	Commuter:	max. 185
	Freight:	max. 5

Rehabilitation/Speed Improvement: Rehabilitation

Description of the Problem: Age, traffic, harsh saltwater environment, and maintenance deferrals over many years have resulted in a steady deterioration of these structures. Emergency repairs have been made from time to time to keep these bridges functioning; however, major rehabilitation or replacement is required to restore the proper structural integrity, mechanical and electrical reliability and provide satisfactory ride quality at the desired speed.

Proposed Solution(s): Replacement or rehabilitation as appropriate.

Project Description: Current and proposed solutions:

- Pelham Bay - rehabilitation (Amtrak)
- Cos Cob - 30-year rehabilitation (CDOT; under construction)
- Walk - 30-year rehabilitation (CDOT; under construction)
- Saga - 10-year rehabilitation (CDOT, under construction); replace movable span in 10 years
- Devon - 30-year rehabilitation (CDOT, under construction)
- Niantic - replacement (Amtrak)
- Thames River (Groton) - Emergency repairs to the trunnion pin have recently been performed. Replacement of bascule span is required in the near future (Amtrak).

Installation of new expansion rail joints on CDOT movable bridges (not currently funded) would permit speed to be increased for all trains at all MB locations.

Current Plans, Status, and Activity: Cos Cob, Walk, Saga, and Devon Bridge rehabilitation programs are underway and fully funded ($59 million). Phase I (completed) rehabilitated the movable spans; Phase II (ongoing) is rehabilitating approach (fixed) spans.

Proposed Amtrak bridge replacement at Niantic and renewal at Pelham Bay are currently unfunded. Amtrak is understood to prefer replacement of as many movable bridges as possible with high-level fixed span crossings to avoid future operation and maintenance of movable bridges. Bridge openings, particularly in the summer to allow pleasure craft access to and from Long Island Sound, are a source of train delay and potentially a source of unreliability of operation. Amtrak's proposed route relocation between Old Saybrook, CT, and Kenyon, RI, would eliminate five movable bridges.

Brief History: Earlier studies evaluated the feasibility and/or merit of rehabilitation versus replacement of each bridge. Plans were prepared under NECIP but not executed for a new Niantic River Bridge and for the rehabilitation of the Thames River Bridge in Groton. A NECIP study recommended Saga be replaced due to its poor condition. A more recent study suggested Saga's movable span could last another 10 years if rehabilitated; rehabilitation has been initiated. A replacement bridge is to be designed starting in the late 1990s.

In-depth bridge studies conducted in the mid-1970s by FRA recommended work be performed at each movable bridge location as follows:

- Pelham Bay Bridge - major structural rehabilitation and mechanical and electrical repairs.
- Cos Cob Bridge - major rehabilitation to movable and fixed spans
- Walk Bridge - major rehabilitation of swing and fixed spans
- Saga Bridge - replacement of existing bridge on the same alignment
- Peck and seven other Bridgeport Bridges: replacement of Peck Bridge and replacement or major rehabilitation of the others. (Peck is considered separately in this report.)
- Devon Bridge - major rehabilitation of movable and fixed spans.
- Connecticut River Bridge - major rehabilitation to bascule lift span and electrical upgrading. (Work was carried out under NECIP).
- Niantic River Bridge - replacement bridge with new bascule lift span on a new alignment. (Work was deferred due to lack of funding.)

- o Shaw's Cove Bridge (New London) - replacement of Amtrak movable bridge on existing alignment (carried out under NECIP).

- o Thames River Bridge - rehabilitation of mechanical and electrical systems on movable span, and structural repairs to fixed spans were completed. The lift span mechanism and lift span itself need replacement.

- o Mystic River Bridge - construction of a new movable bridge on new alignment (carried out under NECIP).

ROW Owner: Indicated above

ROW Maintenance: Amtrak-Pelham Bay, Niantic, Thames River; MNCR, remainder

Dispatching Responsibility: Amtrak, MNCR

Train Operators: Amtrak, MNCR, CONRAIL, P&W

Project Implementation:

(Potential) Funding Agencies/Sources: UMTA, FRA, CDOT

Managing Organization: Amtrak or CDOT/MNCR, as appropriate

Performing Organization: Contractor

Sequencing Considerations:

Other Construction/Logistic Considerations:

Construction-Period Operational Impacts:

Issues and Uncertainties:

Affected Parties:

Purpose or Intended Benefits:

Intercity Service: Long-term reliability, increased speed in some cases, reduced maintenance cost

Commuter Service: Long-term reliability, increased speed in some cases, reduced maintenance cost for those bridges in commuter rail territory.

Principal Beneficiary: For the multibridge project as a whole, benefits are comparable for both intercity and commuter service. Individual bridges differ in impact depending on location.

Uncertainties and Issues: The replacement of Saga is considered to be beyond the timeframe of this study, and is not included in the alternative improvement programs.

Estimated Cost: The rehabilitation of Cos Cob, Walk, Saga and Devon Bridges, now in progress, is estimated to cost $59 million; this work is fully funded. CDOT has estimated the replacement of Saga Bridge (starting in the Year 2000) to cost $78 million (design and construction). Amtrak has no current estimate of the cost of rehabilitating Pelham Bay or replacing Niantic or Thames River Bridges, and no funds have yet been made available. Rough estimates for the rehabilitation/replacement of these three bridges are as follows:

	Estimated Rehabilitation/Replacement Cost (1991 $ in Millions)
Pelham Bay Bridge (Rehab)	$10
Niantic Bridge	$21
Thames River Bridge Movable Span	$33

Project: Fixed Bridges

Project Full Name: Replacement of Aging Open-deck Undergrade Bridges with new Ballasted-deck Structures

Location: Entire New York-Boston Route

Safety Considerations: Long-term margin of safety will decline without improvements.

Revenue Trains per Day:

Intercity:	max.	34
Commuter:	max.	185
Freight:	max.	5

Rehabilitation/Speed Improvement: Rehabilitation and replacement, accompanied by conversion to ballasted-deck structures for improved ride quality and ease of maintenance.

Description of the Problem: Age and deferred maintenance have caused deterioration of undergrade fixed bridges. As a matter of basic infrastructure renewal, repairs or replacement are required at many locations to restore the proper functioning and extend the useful life of these fixed bridge structures. In addition, conversion of the open deck bridges to ballasted deck will improve ride comfort, facilitate attainment of higher superelevation and/or higher speed and have lower maintenance cost.

Proposed Solution(s): Rehabilitate or replace bridges as necessary; convert from open deck to ballasted structures.

Project Description: For MNCR, conversion to ballast decks will involve more than just bridge and track work, since many of the existing open deck bridges are adjacent to passenger stations and are in electrified territory. Conversion involves raising the track top of rail up to 18 inches to accommodate ballast, deck, and through structures. In electrified territory, adjustments may have to be made to wire height. If track rise is close to a station, platform heights may also have to be adjusted.

MNCR has identified 77 open deck bridges for conversion to ballasted deck structures in CT and NY (68 and 9 respectively). Also, 11 existing ballasted deck bridges in CT have been identified for rehabilitation. Many of these bridges are over 90 years old and will need continued repairs and/or replacement.

Amtrak has identified 120 open deck bridges in its Boston Division that it plans to convert to ballast deck, and 20 additional bridges on the Hell Gate Line.

Plans, Status, and Activities: Amtrak and MNCR both have annual bridge rehabilitation and replacement programs. Amtrak plans to convert 140 open deck bridges to ballasted bridges over five plus years subject to availability of capital funding. MNCR's program is limited to essential repairs, generally without conversion to ballasted decks because of lack of funding.

Brief History: NECIP originally contemplated replacement or major rehabilitation of most undergrade fixed bridges between New York and Boston. [A total of 363 fixed bridges were included in the 1977 NECIP Baseline Implementation Master Plan--69 on the Hell Gate Line, 128 between New Rochelle and New Haven and 166 between New Haven and Boston.] Due to budget cuts and changes in spending priorities, many of these bridges were dropped from the program or received only minor repairs under NECIP. Both Amtrak and MNCR have continued to attend to minimum essential repairs but neither agency has had sufficient funds to tackle the bulk of the program.

ROW Owner: Amtrak/CDOT/MTA/MBTA

ROW Maintenance: Amtrak/MNCR

Dispatching Responsibility: Amtrak or MNCR

Train Operators: Amtrak, MNCR

Project Implementation:

(Potential) Funding Agencies/Sources: FRA, UMTA, CDOT

Managing Organization: Amtrak, MNCR and CDOT, as appropriate

Performing Organization: Amtrak and MNCR

Sequencing Considerations: Must coordinate track outages and other work with bridge work.

Other Construction/Logistic Considerations: Accompanying catenary and platform work if required. Overhead structures may also be impacted.

Construction-Period Operational Impacts: Most work would require continuous track outages.

Issues and Uncertainties:

Affected Parties: Amtrak, MNCR, CDOT, MBTA

Purpose or Intended Benefits:

Intercity Service: Improved margin of safety and improved ride comfort. With other improvements, bridge renewal will permit higher speeds.

Commuter Service: Improved margin of safety and improved ride comfort. With other improvements, bridge renewal will permit higher speeds.

Principal Beneficiary: Many of the bridges are in east of New Haven and their improvement will represent an important improvement in ride quality, while enabling other projects to increase speed. Individual bridges differ in impact depending on location, but intercity service is seen as the principal beneficiary.

Uncertainties and Issues: Availability of funds; sequencing factors limit rate of progress.

Estimated Cost: One hundred-twenty million dollars for replacement of 77 Metro-North undergrade bridge structures, including associated modifications to track, catenary, retaining walls and platform locations/elevations. Additionally, 11 ballasted deck structures in CT must also be rehabilitated. Forty-eight million dollars for modifications of 120 Amtrak bridges to ballast decks between New Haven and Boston. Fifty million dollars for Hell Gate Line ballast deck conversion program (20 spans) and modifications to the Hell Gate viaduct and Hell Gate Bridge structure, deck, lighting, and walkways.

Project: Harold Interlocking

Project Full Name: Improvements and Grade Separation at Harold Interlocking

Location: Borough of Queens, New York City (MP E3 - E4)

Safety Considerations: Not a factor

Revenue Trains per Day:		
	Intercity:	34
	Commuter:	397 (LIRR); More than 600 LIRR and NJT, including deadhead
	Freight:	0

Rehabilitation/Speed Improvement: Speed Improvement

Description of the Problem: The Harold Interlocking, 4 miles from Penn Station, is where the two-track Amtrak mainline from New Rochelle joins six LIRR tracks. All traffic to and from Penn Station passes through the "F" interlocking (which also controls Amtrak, LIRR and NJ Transit access to the adjacent Sunnyside Yard) and the four East River Tunnels. Two of the tunnels are for exclusive use by LIRR; the other two are shared by Amtrak, LIRR, and the NJ Transit trains enroute to Sunnyside for storage). The convergence of this level of traffic in the vicinity of Harold interlocking has a high potential for congestion and delay, much of which (for westbound moves) is related to tunnel and station capacity. However, for eastbound Amtrak trains, the need to cross the LIRR tracks has a particularly high propensity to create delays.

Penn Station-bound Amtrak trains do not enter the interlocking until a route is available and so do not reduce throughput for the LIRR. Eastbound Amtrak trains must traverse three crossovers to reach the Amtrak Hell Gate lead track which then flies over three westbound LIRR Mainline and Port Washington tracks. The eastward Amtrak move blocks any eastward move of LIRR from either Penn Station or Long Island City.

Both of the above situations promote delays, particularly during peak periods. As traffic growth continues, the peak periods are lengthening.

Proposed Solution(s): A grade separation (flyover) between the Amtrak and LIRR tracks would reduce diverging moves and permit higher speeds.

Project Description: No project is currently being seriously examined. Flyover designs have been prepared for Harold in the past but never implemented due to cost and complexity of construction. A natural long-term solution at Harold would include flyovers for both eastward and westward Amtrak moves. However, the cost and complexity of implementing a solution of this nature in a physically crowded area would be very substantial. A detailed study of this critical junction point is required to develop an appropriate solution. A workable plan would benefit both Amtrak and LIRR. However, avoidance of substantial delays for LIRR service during any construction period would be a particularly challenging requirement.

Current Plans, Status, and Activity: Recent construction projects at Harold have improved train routings. Further study will be required to determine at what point delays associated with Harold will become so severe as to warrant the necessary large investment for any solution. In addition, the value of improvement at Harold will depend to some degree on the effectiveness with which other, more general problems with tunnel and station capacity are met.

The MTA is just concluding a major study of Penn Station capacity and utilization. However, Harold is not treated in detail.

Brief History: The Penn Station-Harold area has long been a significant NEC bottleneck. A major reconfiguration of the Harold interlocking has recently been completed through a cooperative effort by Amtrak, LIRR, and FRA. This appears to have reduced delays at Harold to a tolerable level, but delays are still common and Amtrak and LIRR anticipate substantial increases in service.

ROW Owner: LIRR

ROW Maintenance: LIRR

Dispatching Responsibility: LIRR

Train Operators: Amtrak, LIRR

Project Implementation:

(Potential) Funding Agencies/Sources: FRA, UMTA

Managing Organization: LIRR

Performing Organization: Contractor

Sequencing Considerations:

Other Construction/Logistic Considerations: Maintenance of near-normal LIRR operations will impose many constraints on the construction process.

Construction-Period Operational Impacts: Potentially severe delays for LIRR

Affected Parties: LIRR, Amtrak

Purpose or Intended Benefits

Intercity Service: Reduced delays and improved reliability, particularly for eastbound service.

Commuter Service: Reduced delays and improved reliability.

Principal Beneficiary: Both services would benefit substantially, but the much higher volume of commuter service suggests that it will be the predominant beneficiary.

Uncertainties and Issues: Construction impacts, traffic and capacity analysis supporting criticalness of project

Estimated Cost: Very approximate estimate for a 5000-foot single-track eastbound flyover (over 3 LIRR tracks at Harold), including minor track realignment and associated signal and catenary work: $65 million.

Project: Shell Interlocking

Project Full Name: Reconfiguration and/or Grade Separation at Shell Interlocking, New Rochelle, NY

Location: At and immediately west of New Rochelle station (MP 16 - 17, CP 216)

Safety Considerations: Not a factor

Revenue Trains per Day:	Intercity:	34	
	Commuter:	185	
	Freight:	1	
Total Trains per Day:		1991	2010 (Est.)
	Intercity:	34	76
	Commuter:	208	288
	Freight:	1	

Rehabilitation/Speed Improvement: Speed Improvement

Description of the Problem: There is a high and increasing likelihood of Amtrak delays due to conflicts with MNCR traffic, both in crossover where the Hell Gate Line of the Amtrak New York Division diverges to the south from the MNCR New Haven - Grand Central Line, and, more seriously, where northbound Amtrak merges with outbound MNCR traffic. The present interchange is at low speed which requires excessive time through CP216.

The right-of-way is constrained by retaining walls on each side, complicating the nature and implementation of any solution. Environmental and other considerations, including an adjacent cemetery, constrain major changes in alignment.

Proposed Solution(s): Two alternatives are being considered to reduce the time required to traverse the interlocking plant:

(1) FLYOVER: Depression of the two eastbound MNCR tracks and elevation of the Hell Gate Line tracks on an overpass.

(2) AT-GRADE: Changes to track configuration and turnouts in the vicinity of New Rochelle which would increase speeds through the area and reduce conflicts.

Note: Due to the potential for queuing and cascading of delays, improvements at Shell are operationally linked with island platforms at Stamford. The overall benefit from projects at Shell and Stamford, taken together, would be a reduction of train conflicts and improved reliability of service substantially greater than the sum of the individual benefits from each.

Project Description

1. FLYOVER

There are several schemes to construct a flyover for the replacement of the existing interlocking for crossing from outer (Hell Gate Line) to center high-speed tracks on Metro-North. All schemes accomplish this by depression of two Metro-North eastbound tracks and elevation of the two Hell Gate Line tracks to pass above the Metro-North tracks.

SCHEME 1. The double track flyover would begin just west of the New Rochelle station, but would eliminate the present station as a stop for Amtrak service; a new center island platform, included as a modification called Scheme 1A, would still permit Amtrak station stops for selected trains. High-speed turnouts, increased superelevation and reconfiguration of the curve at the beginning of the Hell Gate Line would allow minimum speed limits of 45 MPH on clear signal.

Under Schemes 1 and 1A, Amtrak grades would be approximately 2.5%, with Hell Gate tracks raised 15 feet; MNCR grades would be about 2.0%, with tracks depressed 5 feet. Both flyover schemes require major realignment of the 4 track Metro-North railroad to the north in the vicinity of the station, in order to ease horizontal curvature. Substantial portions of the civil/structures work would necessarily be done by contract, as opposed to Metro-North force account, thereby complicating issues of control and access during construction.

The environmental impacts of Scheme 1 are moderate. The overhead Center Street bridge would be rebuilt and elevated 3 to 5 feet; a new undergrade Webster Avenue railroad bridge would be built on the Hell Gate Line. New retaining walls would support the overpassing track structure in the approaches to the flyover. Scheme 1A would require in addition the construction of a new pedestrian walkway with handicap access to the new island platform. (Note: it is the position of Metro-North that Amtrak trains could not stop and block traffic at the island platform during peak traffic.) Both schemes would have noise impacts associated with the elevated tracks on the flyover.

SCHEME 3. The Double Track flyover would be built approximately 3000 feet east of the present station. It would require the construction of new Tracks 6 and 8 adjacent to the existing MNCR 4-track mainline, extending from the Hell Gate Line to a point about 6000 feet east of the station. Track grades associated with this flyover are roughly equivalent to those of Schemes 1 and 1A. Minimum speeds of 45 MPH would be allowed on clear signal.

The environmental impacts include rebuilding the overhead bridges at Center, Division, and Memorial Streets to provide horizontal clearance for the two new tracks. A new two-track undergrade railroad bridge would be required at Cedar Street. The bus stop and street adjacent to Railroad Place would require rebuilding, and there might be some impact on the historic cemetery.

There is also a Scheme 3 - Single Track version which differs from the above primarily in that there is one bypass track through the station area rather than two. This reduces some costs and does not threaten relocation of the cemetery area, nor does it impact the bus stop and street adjacent to Railroad Place. Therefore its environmental impacts are somewhat less than the Scheme 3 double track. However, it reduces Amtrak to single track access from the Hell Gate Line through the platform area, requiring Amtrak to schedule adequate separation for opposing moves.

2. AT-GRADE

Two schemes have undergone scrutiny for an at-grade, level junction between the Metro-North main commuter line to Grand Central Terminal and the Amtrak Hell Gate Line to Penn Station.

Schemes M and O both rely upon new construction of Track 6 adjacent to the south side of the existing south platform, through the inside curve to the Hell Gate Line. They also utilize high speed crossovers east of North Avenue and Cedar Street to "ladder" across the 4-track mainline for diverging and converging moves, shifting this activity away from the immediate area of the Hell Gate Line intersection. Both schemes, due to environmental concern and reduction of horizontal curvature, require the shift of the 4-track mainline to the north in the vicinity of the station. This requires the reconstruction of the overhead Center Street, Division Street, and Memorial Highway bridges to provide the necessary horizontal clearances. One result of this is that at-grade solutions turn out to be relatively more costly than expected.

Scheme M results in a single-track high-speed Hell Gate Line connection for about a one-mile distance. Amtrak therefore must schedule adequate separation for opposing moves. The environmental impacts are generally somewhat less than those associated with flyover Scheme 3, and probably equal to or greater than those associated with Scheme 1.

Scheme O results in a single track high speed line connection to the Hell Gate Line for about a 2 1/2 mile distance, with the same scheduling implications for Amtrak as Scheme M. The environmental impacts also include the construction of additional new track around the curve east of the yard.

Current Plans, Status, and Activity: Design alternatives are being evaluated by Amtrak, MNCR and FRA. $25 million is earmarked for this project in the FY91 FRA budget as part of capital grants to Amtrak for improved Boston-Washington high-speed service.

Brief History: The Shell Flyover was included in NECIP plans in the 1970s, but was ultimately eliminated due to funding constraints. As far back as the 1920s, references have cited the need for improvements in the configuration of tracks at Shell.

ROW Owner: MTA (Near and extending over boundary with Amtrak-owned Hell Gate Line)

ROW Maintenance: MNCR

Dispatching Responsibility: MNCR

Train Operators: Amtrak, MNCR, Conrail

Project Implementation:

(Potential) Funding Agencies/Sources: FRA (Amtrak Capital Grant for Boston-Washington high-speed service), UMTA

Managing Organization: MNCR

Performing Organization: MNCR, contractor

Sequencing Considerations: The adoption of any proposed scheme to improve Shell Interlocking will entail a construction period of at least 48 months. During this period, there will be a loss of flexibility in operations which will need to be considered when scheduling other construction or maintenance activities in areas adjacent to, or impacted by, Shell.

Other Construction/Logistic Considerations: Due to the constrained nature of the construction site in an existing "open cut" on an active 4-track mainline with overhead catenary, preliminary analysis of construction feasibility has been undertaken by FRA contractor DeLeuw, Cather/Parsons. This analysis has not convinced MNCR that flyover Schemes 1 and 1A can be built without track outages and serious impact on service.

Construction-Period Operational Impacts: Special attention will be required in defining the operational requirements of MNCR and Amtrak in any Shell construction contract, to minimize impacts on service. Such impacts are potentially serious, but currently considered by FRA and Amtrak to be manageable. As stated above, MNCR has serious reservations regarding the impacts of flyover construction Schemes 1 and 1A.

Affected Parties: Amtrak, MNCR

Purpose or Intended Benefits:

Intercity Service: All schemes would result in passage through the area at 45 MPH or better on clear signal (now 15 MPH for Amtrak). Flyover schemes have higher traffic capacities than at-grade schemes, and therefore lower potential for conflicts. Flyover Schemes 1 and 3-Double Track have less potential for traffic conflicts than flyover Schemes 1A and 3-Single Track. Reduced pad and increased schedule reliability are major benefits for Amtrak. Improvements in capacity at Stamford are considered essential to fully realizing the benefits of reduced trip times through Shell.

There is considerable debate between Amtrak, MNCR, and FRA as to the degree to which benefits can be attained under the various schemes.

Commuter Service: Passage through area at 45 MPH (now 30 MPH); reduced track maintenance cost for MNCR; simplified dispatching. Capacity improvements at Shell can only be fully achieved with capacity improvements at Stamford. Commuter service especially may be considered to suffer periodic disbenefits of increased trip times due to temporary construction impacts on operations.

Note: Due to the potential for queuing and cascading of delays, improvements at Shell Interlocking are inherently linked with island platforms at Stamford. The overall benefit from projects at Shell and Stamford, taken together, would be a reduction of train conflicts and improved reliability of service substantially greater than the sum of the individual benefits from each. However, the Stamford project would be highly beneficial to commuter and Amtrak services, without regard to the Shell project.

Principal Beneficiary: Conflicts at Shell are serious problems for both services, and commuter traffic is substantially higher than intercity. However, the potential for very lengthy delays for Amtrak trains that miss their slot suggest that both services would benefit to a comparable degree.

Uncertainties and Issues: Critical issues are construction costs and environmental impacts of alternative schemes, loss of flexibility and potential delays for MNCR throughout a long construction period, and whether an at-grade approach could carry projected future traffic without serious conflicts and delays.

A committee of representatives from Amtrak, MNCR, and FRA has studied these questions to define the best options for at-grade and flyover solutions to the Shell problem using traffic projections for the year 2010. The positions of the participants is summarized below:

	BEST AT-GRADE	BEST FLYOVER
Amtrak	Scheme M	Scheme 1 *
MNCR	Scheme M	Scheme 3
FRA	Scheme M = Scheme O	Scheme 1 *

* Scheme 1 would eliminate the ability of Amtrak to stop at the existing New Rochelle station, resulting in lost connectivity with MNCR. Therefore the construction of a new station on the Hell Gate line some distance away would be required, at a cost that Amtrak estimates at $3M to $5M.

The committee also found that the projected future traffic levels exceed the viable operating capacity on the New Haven Line between New Rochelle and CP 223 ("PIKE") during peak periods. Therefore, it was unanimously recommended that an electrified siding be constructed east of PIKE.

Other differences between committee members may be resolved only through use of sophisticated computerized traffic simulators which will analyze the myriad variables of the alternative schemes, and their respective construction scenarios.

Estimated Cost: The following conceptual design estimates, prepared by DeLeuw, Cather/Parsons, include design, management, and 30% contingency for all schemes and are expressed in 1991 dollars:

	COST(1)	DURATION(2) (MOS.)
SCHEME M, AT-GRADE	$40M	48
SCHEME O, AT-GRADE	$38M	48
SCHEME 1, FLYOVER AT JUNCTION	$47M(3)	51
SCHEME 1A, FLYOVER W/ ISL. PLAT.	$51M	57
SCHEME 3, DBL. TK., W/ FLYOVER E. SHELL	$73M	66
SCHEME 3, SGL. TK., W/ FLYOVER E. SHELL	$61M	57

(1) To all schemes must be added the cost of an electrified side track east of CP 223 ("PIKE") of $1.4M, necessary to turn MNCR trains during peak periods of operation; it would be constructed prior to the start of any of the above schemes.

(2) Duration is construction only; does not include the time for design and contract award.

(3) Scheme 1 eliminates the present Amtrak stop. A new station to be constructed on the Hell Gate Line is estimated by Amtrak to be in the range of $3M to $5M. This study did not address a new Amtrak station at New Rochelle; however, its cost must be added to Scheme 1.

For the purpose of providing a budgetary estimate for New Rochelle Interlocking, a figure of $55M in 1991 dollars has been selected in this study. It does not represent the endorsement of any scheme, and is considered to be a reasonable cost estimate based on what is known at this time.

Project: Stamford Island Platforms

Project Full Name: Provision of Center Island Platforms at Stamford Transportation Center (Stamford Station)

Location: Station at Stamford, CT (MP 33)

Safety Considerations: Not a factor

Revenue Trains per Day:

Intercity:	34
Commuter:	185
Freight:	3

Rehabilitation/Speed Improvement: Speed Improvement

Description of the Problem: Stamford Station is the highest volume outlying station on the Metro-North system, with more than 11,000 riders boarding or detraining on a normal weekday. Over 235 MNCR revenue and nonrevenue trains per day pass the station, 185 having scheduled stops. It serves as an interchange point for New Haven Line local and express services as well as for the New Canaan Branch connection. It is also seen as an increasingly important station for Amtrak. The several MNCR markets it serves (including intrastate and reverse commuting) are anticipated to experience substantial future growth.

Reflecting the critical role of this location, a new station has recently been constructed as part of a major intermodal terminal, jointly funded by the city, the state, FRA, and UMTA. Approximately one-half of all MNCR New-Haven Line commuter trains originate or terminate their runs at Stamford. A large MNCR yard just east of the station is reached through restricted speed signal aspects (15 MPH); a relatively lengthy time is required to clear the interlocking. Since Stamford serves as a major commuter transfer point between lines and between express and local trains, the sequencing of trains at each side platform is critical. (The platforms are outside of the outermost of four through-tracks, and thus available to only two tracks--two trains--at a time.) This imposes a constraint which causes delay to a single train--which can occur frequently as a result of moves to or from the yard--to cascade to other trains, both MNCR and Amtrak.

Any delay to a westbound Amtrak train in the morning peak period can cause it to miss its "slot" at Shell Interlocking, greatly increasing the overall delay. In the evening peak, delays from Stamford for eastbound trains can create congested flow as far back as New Rochelle, thereby exacerbating the potential for delay at Shell Interlocking.

Thus, the key problems at Stamford are a combination of inadequate platform access and capacity, restrictive speeds for all trains, and a conflict-generating track configuration. This location currently experiences substantial congestion, delays and problems in sequencing of trains, a situation that can only worsen with time.

Proposed Solution(s): Construction of additional side or island platforms, permitting station stops by mainline as well as local trains, thereby increasing platform capacity. This should be accompanied by changes in track configuration and signaling, including the use of high-speed crossovers, to minimize delays associated with yard and other moves.

Project Description: The alternatives now being considered include various configurations of island and side platforms. Issues of platform length, associated track reconfiguration, and especially the degree of rail bridge reconstruction over Washington Blvd. to address inadequate horizontal and vertical clearances, will have major impacts on cost and complexity of the project.

Current Plans, Status, and Activity: At the time of this writing, CDOT, in coordination with MNCR and Amtrak, is directing a study to analyze Stamford station to define the requirements for adequate train and passenger capacity. CDOT's contractor is preparing layouts and cost estimates of alternatives. No funding is presently available for construction.

Brief History: This project was proposed in the NECIP, originally calling for three island platforms, but was dropped when the scope and funding of NECIP was reduced. In the 1985 version of the NECIP plan, two 1020-foot (12-car) platforms and major bridge reconstruction were envisioned, at a cost of $55 million. In 1988, MNCR submitted to CDOT a plan for two 850-foot (ten-car) platforms, which would minimize the need for new bridge construction and major track and catenary realignment. Major platform and station rehabilitation has already been accomplished at Stamford using a design readily adapted to the island platforms.

ROW Owner: CDOT

ROW Maintenance: MNCR

Dispatching Responsibility: MNCR

Train Operators: MNCR, Amtrak, Conrail

Project Implementation: CDOT

(Potential) Funding Agencies/Sources: UMTA, FRA, CDOT

Managing Organization: CDOT

Performing Organization: Contractor

Sequencing Considerations: Work at Stamford must be closely coordinated with construction at Shell Interlocking

Other Construction/Logistic Considerations: Bridge reconstruction involves City of Stamford, and will impact automobile access to the station. Platform design must meet current requirements of access by disabled individuals.

Construction-Period Operational Impacts: There is a potential for substantial temporary delay to commuter and intercity service at peak hours.

Affected Parties: Amtrak, MNCR, CDOT, Conrail

Purpose or Intended Benefits:

Intercity Service: Significant trip time reduction, based on higher speed through the station, reduced dwell time for stopping trains, and improved reliability due to less congestion; improved Amtrak-commuter connections.

Commuter Service: Shorter running time, significantly improved reliability, doubling of afternoon-evening peak-hour capacity; also, improved Amtrak-commuter connections. Reduced delays due to yard-station congestion; improved scheduling flexibility.

Note: Due to the potential for queuing and cascading of delays, island platforms at Stamford are inherently linked with improvements at Shell Interlocking. The overall benefit from projects at Shell and Stamford, taken together, would be a reduction of train conflicts and improved reliability of service substantially greater than the sum of the individual benefits from each. However, the Stamford project would be highly beneficial to commuter and Amtrak services, without regard to the Shell project.

Principal Beneficiary: Improvements at Stamford would be highly beneficial to both commuter and intercity services. However, given the much higher volume of commuters, and the fact that they are much more likely to passing that region at congested peak hours, commuter services are judged to be the principal beneficiary.

Uncertainties and Issues: The future operation of the station needs to be further defined in order to select the best alternative of the proposed improvements. Some of the rail transportation issues are: (1) Platform Length: Amtrak prefers platforms of sufficient length (1000 feet) to permit full access by trains 12 cars in length. (2) Track 1 access to platform: CDOT and MNCR prefer that Track 1 be an express track (for "overtakes"). (3) Design for through traffic: Improvements should address speeds, use of high-speed crossovers, platform safety. (4) Capacity of station: Passenger access and egress require further analysis.

There are also highway related issues in the vicinity of the station, specifically the vertical and horizontal clearances where Washington Blvd. passes beneath the station/track complex. The scope of any reconstruction associated with the latter problem could have the effect of increasing total costs by a factor of two or more.

Estimated Cost: Estimated cost of seven (7) alternatives (for track/platform work only) prepared by CDOT's consultant range from $9 million-$19 million (January 1994 dollars). High-speed crossovers, additional interlocking work, and bridge reconstruction could add substantially to the cost. CDOT's estimate of Stamford Improvements range from $20-40 million. For the purposes of this study, a budgetary estimate of $30 million is used.

Project: New Haven Terminal Area

Project Full Name: Reconfiguration of Tracks at New Haven Station and Yard

Location: New Haven Station Area (MP 72 - 73)

Safety Considerations: Not a factor

Revenue Trains per Day:

Intercity:	34
Commuter:	60 (NYC), 13 (Old Saybrook)
Freight:	4

Rehabilitation/Speed Improvement: Because of age and poor condition, the trackwork and interlockings within the New Haven Terminal area need to be renewed and/or replaced. Speed and signalling improvements, while discretionary, can be made at a modest incremental cost to the basic rehabilitation and should therefore be implemented in conjunction with the planned renewal.

Description of the Problem: New Haven is the terminus of MNCR service eastbound and CDOT commuter service, operated by Amtrak westbound; it is the eastern end of electrified territory. The yard area includes a major MNCR/CDOT maintenance facility. The yard itself and the interlocking control machine has deteriorated, and now generates substantial maintenance expenses.

All Amtrak service stops at New Haven not only as a station stop but also to switch motive power and train crews; electric propulsion is used from New Haven westward. To the east, most of the Amtrak service operates over the Shore Line, but several trains go north to Springfield. The existing track configuration at New Haven is based upon its use in the early part of the century as a freight yard that was the junction between steam and electric service. There is substantially more trackage than necessary, and it is not possible to traverse the station area without crossover moves. Sharp curvature east of the yard, low-speed turnouts and signal restrictions typically hold speed to 10 MPH or less. In addition, the current configuration is less than convenient for changing motive power on Amtrak trains (exchanging electric traction for diesel or vice versa).

Proposed Solution(s): Renewal and reconfiguration of entire station/yard area. Possible extension of project scope to include Fair St. - Mill River.

Project Description: The proposed improvement project includes major changes in track configuration such that no diverging (crossover) moves are required for Boston-New York through express trains, so that speeds up to 50 MPH can be used. Pocket tracks to facilitate motive power changes are to be included in the design. Universal crossover capability will be provided at both ends of the yard. The project would include improvements to the yard area, used by MNCR for nightly storage of commuter coaches, and major renewal of track, turnouts, drainage, and the remaining portions of the interlocking. New track, turnouts, drainage, and interlockings will be provided to reduce maintenance expenses.

Additional speed improvements are potentially feasible east of Fair Street (between Fair St. and Mill River Junction) by eliminating excess trackage, realigning remaining tracks to reduce curvature and adding superelevation to permit higher track speeds. However, curve realignments are limited due to constraints of overhead structures and tunnels. Fifty mph speeds could be achieved in this segment through ROW realignments. This project segment is not currently within the scope of the proposed improvement project.

Cab signals need to be installed on both approaches and through the terminal area. Currently, entering locomotives lose cab signal and receive a restricting indication. Moves in and out of the station are then made at 15 MPH. Additional design work is required to clarify the potential time savings and cost of such changes. In order to attain speed improvements, coordinated on-site control of the total interlocking is necessary.

Current Plans, Status, and Activity: CDOT has purchased 45 acres of the land from Amtrak and prepared a new conceptual design for the yard. A CDOT design study currently underway is based on this conceptual design and an agreed-upon track configuration dated August 3, 1990. This study calls for a 45 MPH route through New Haven, but this design extends eastward only to Fair Street, the boundary between CDOT and Amtrak ownership of the right-of-way. $12M in initial funding is being sought by CDOT from UMTA grant for interlocking replacement. The Amtrak FY91 appropriation includes $5M for improvements at New Haven.

Brief History: Improvement of the track configuration at New Haven was part of the original NECIP plan, but was never accomplished. Substantial design work had been performed when the project became dormant in 1981. A new high-level platform has recently been added to the three others already existing, with extension of the two center platforms to 1100 feet a possible future improvement.

ROW Owner: CDOT (Amtrak east of MP 72.8)

ROW Maintenance: MNCR (Amtrak East of MP 72.8)

Dispatching Responsibility: MNCR westbound; Amtrak eastbound

Train Operators: MNCR, CDOT/Amtrak, Amtrak

Project Implementation:

(Potential) Funding Agencies/Sources: UMTA, FRA, CDOT

Managing Organization: CDOT/MNCR
Performing Organization: MNCR

Sequencing Considerations: Should be phased with the CDOT Stamford Yard Project.

Other Construction/Logistic Considerations: Installation of new interlocking and signal control machinery. Location of improvements overlaps boundary between MNCR/CDOT and Amtrak responsibility, requiring coordination between users.

Construction-Period Operational Impacts: No major impacts.

Affected Parties: MNCR, CDOT, Amtrak

Purpose or Potential Benefits:

Intercity Service: Substantial travel time reductions due to higher speeds entering and leaving plus significant reduction in pad due to more efficient operation.

Commuter Service: Significant reductions in travel time; significantly reduced facility maintenance costs for MNCR.

Principal Beneficiary: Both services would benefit substantially, and traffic volumes are similar. Commuter and intercity operations are judged to benefit approximately equally.

Uncertainties and Issues: Close coordination is required between CDOT, Amtrak and MNCR not only in station/yard design, but also in integrating the easterly approach and yard designs and construction. Amtrak has emphasized the importance of accommodating the handling of mail and baggage. A joint control system will be needed for control of interlockings at each end of the yard. Operational flexibility is particularly important.

The overall project is likely to involve multiple funding sources which must be integrated. There is definitely a need to resolve the scope and extent of improvements at New Haven.

Estimated Cost: CDOT has estimated the cost of New Haven Station/Yard reconfiguration at $55 million. The scope of work has not been defined well enough yet to prepare a detailed estimate. For purposes of this report CDOT's cost estimate rounded up to $60 million is adopted (subject to further refinement as the scope is better defined).

Expansion of the project scope to include the territory on the east from Fair St. to Mill River could increase project size, but could provide additional time savings through track removals and curvature reductions on the existing alignment/ROW. (A budgetary allotment of $20 million is proposed, but project is not programmed.)

Project: New Haven-Norwalk Fourth Track

Project Full Name: Restoration of New Haven-Norwalk Fourth Track

Location: New Haven Line from Norwalk to New Haven (MP 42 - 72)

Safety Considerations: Safety is not a factor.

Revenue Trains per Day:

Intercity:	34	
Commuter:	60	(MNCR)
Freight:	5	

Rehabilitation/Speed Improvement: Speed Improvement

Description of the Problem: Commuter traffic between New Haven and Norwalk is modest enough that three tracks are currently sufficient for the combined needs of MNCR, Amtrak, and Conrail. In view of the capabilities of the relatively new signal system in place (CTC with reverse signaling on all tracks), three tracks will be sufficient for the near future. Between New Haven and Devon the fourth track (designated Track 3) had deteriorated to the point that the fourth track would have required a $10 million investment to restore for passenger service. Part of that track has been removed; west of MP 65 the track is out of service, with several undergrade bridge spans removed. Similarly, the fourth track from Devon to Norwalk requires a substantial maintenance expenditure to keep in operation for revenue traffic. From Devon to Norwalk, Track 2 will have reached the end of its service life in approximately 10 years, and CDOT/MNCR plans have included its removal at that time.

Amtrak and FRA have expressed concern that the three remaining tracks will not be sufficient for the level of traffic and intercity speeds anticipated early in the next decade. Detailed analysis will be required to determine that traffic at which a fourth track is required, but initial examination indicates that retention/replacement of the track will be needed by early in the next decade.

Proposed Solution(s): Should future analysis confirm that the capacity concerns are justified, the fourth track will have to be replaced. (The Pequonnock River bridge replacement project at Bridgeport will provide four tracks.)

Project Description: The fourth track from New Haven to Norwalk will be replaced when needed. It will be electrified and constructed to standards supporting intercity and local commuter services.

Current Plans, Status, and Activity: No current plans or activity.

Brief History:

ROW Owner: CDOT

ROW Maintenance: MNCR

Dispatching Responsibility: MNCR

Train Operators: MNCR, Amtrak, Conrail

Project Implementation:

> (Potential) Funding Agencies/Sources: FRA, Amtrak
>
> Managing Organization: CDOT/MNCR
>
> Performing Organization: MNCR
>
> Sequencing Considerations:
>
> Other Construction/Logistic Considerations:
>
> Construction-Period Operational Impacts: Small

Affected Parties: MNCR, CDOT, Amtrak

Purpose or Intended Benefits:

> Intercity Service: Assurance of unimpeded service and operational flexibility
>
> Commuter Service: Assurance of unimpeded service and operational flexibility
>
> Principal Beneficiary: The additional track is required primarily to support intercity operations. Although commuter services will also benefit from the additional future capacity, intercity service appears to be the predominant beneficiary.

Uncertainties and Issues: At present traffic levels the fourth track is not required; at projected future levels of traffic, it's presence will assure optimal service and operational flexibility.

Estimated Cost: The estimated cost to replace/reinstall the fourth track from Devon-New Haven, plus install new welded rail on Track 2 from Norwalk-Devon, is $20 million, excluding concrete ties which are included in the proposed Track Program. Conversion of two bridges to ballasted deck design is included, as well as associated signal and catenary modification.

Project: Canton Viaduct

Project Full Name: Rehabilitation of Viaduct in Canton, Massachusetts

Location: Canton, MA (MP 213.6)

Safety Considerations: Not a factor

Trains per Day:

	Intercity:	24
	Commuter:	57
	Freight:	1

Rehabilitation/Speed Improvement: Speed Improvement

Description of the Problem: The Canton Viaduct is a multiple-arch granite masonry structure approximately 615 feet long and 22 feet in width. At its highest point, it stands about 50 feet above the level of the East Branch of the Neponset River. It carries both intercity and commuter rail traffic on two tracks. However, there are currently speed restrictions for trains on the Viaduct for two reasons: (1) there is substandard horizontal clearance (11'-8 3/4") to permit two trains operating at high speed in opposing directions, and on parallel tracks, to pass each other safely with adequate clearance; and (2) inadequate side clearance from the handrails for southbound Bombardier and Pullman coaches should there be a failure in their airbag suspension systems. The result of these concerns is that train speeds are generally limited to 80 MPH, with 20 MPH limit on southbound Track 1 MBTA Pullman and Bombardier cars.

Proposed Solution(s): MBTA's consultant (see below) proposes constructing a new cantilevered concrete deck 8 feet wider than the existing top surface of the viaduct. Amtrak is not convinced that anything other than minor repairs is necessary.

Project Description: In a report prepared on the behalf of the MBTA by Vanasse Hangen Brustlin, Inc. (VHB), a proposal is presented to remove the railings and the top layer of capstones and build a cantilevered deck 8 feet wider than present. The waterproofed deck will act as a ballast retainer, providing four foot walkways on each side of the structure. Portions of existing concrete arches will be replaced with steel-reinforced concrete. Double track railroad will be installed with necessary clearance (13 ft.) for 100+ MPH service.

Current Plans, Status, and Activities: A plan to address the viaduct problems was developed by VHB in March 1991, for MBTA. One point five million dollars was been appropriated to Amtrak in FY91 for this project.

Brief History: Construction of the Viaduct to support a single track was completed in 1835 by the Boston and Providence Railroad. In 1860, large wooden timbers were placed across the top of the viaduct to support double tracks. The wooden timbers were augmented by iron trusses in 1880. In 1909, all 42 masonry arches were strengthened with concrete arch supports. The structure was placed on the National Register of Historic Places in 1984. A report and action plan for the needed rehabilitation was prepared for MBTA early in 1991.

ROW Owner: MBTA

ROW Maintenance: MBTA/Amtrak

Dispatching Responsibility: MBTA/Amtrak

Train Operators: Amtrak

Project Implementation:

(Potential) Funding Agencies/Sources: FRA (Amtrak Capital Grant for Boston-Washington high-speed service); MBTA

Managing Organization: MBTA

Performing Organization: Contractor

Sequencing Considerations: Operational delays due to construction should be phased with other repair and maintenance activities.

Other Construction/Logistic Considerations: Physical constraints at the work site will add to the cost and duration of construction.

Construction Period Operational Impacts: Construction of a new cantilevered deck would require single track occupancy during an extended period.

Current Plans, Status, and Activity: Available funding of $1.5M can support MBTA's proposed site investigation and design, but not construction; $1.5M may be adequate for Amtrak's minor repairs.

Affected Parties: MBTA, Amtrak, Conrail

Purpose or Intended Benefits:

Intercity Service: Accommodate higher speeds and eliminate delays associated with commuter operations.

Commuter Service: Increase speeds and reduce delays due to present speed restriction (20 MPH) southbound on some equipment.

Principal Beneficiary: Although the principal cause of current delays is related to characteristics of some current commuter rolling stock, delays at Canton are damaging to intercity service as well, and traffic is comparable. Benefits are judged approximately equal for each service.

Uncertainties and Issues: Further review of speed profile through this area is required. A consensus should be reached between Amtrak and MBTA regarding the scope of repairs necessary.

Estimated Cost: Ten million dollars has been estimated in the VHB study. Considerations of continued railroad operations and night/weekend work could increase the project cost severalfold. Operational requirements and constructibility require further study. Lacking more definitive information, this study reflects the estimated cost of $10M.

Project: Track Improvements

Project Full Name: Upgrade of Track Structure to Support High Speeds (Ties, Rail, Turnouts, Sidings, Superelevation, Spirals).

Location: Throughout, but most heavily between New Haven and Boston

Safety Considerations: Speed cannot be raised above 110 mph without FRA waiver. To date, FRA has insisted on concrete ties and frequent inspection for speeds higher than permitted on Class 6 (110 mph) track.

Revenue Trains per Day:	Intercity:	max. 34
	Commuter:	max. 185
	Freight:	max. 5

Rehabilitation/Speed Improvement: Speed Improvement (required for operation above 110 MPH under current standards).

Description of the Problem: High-speed operation requires improved track structures for safety and passenger comfort. Sidings will be needed to facilitate simultaneous operation of high-speed intercity and commuter trains. Track must be relined and resurfaced to achieve greater superelevation and appropriate spiral transitions.

Proposed Solution(s): Installation of concrete ties, CWR, high-speed crossovers, and passing sidings or third main track as needed. Increase of superelevation in many curves and/or lengthening of spirals.

Project Description: Installation of concrete ties and CWR in locations where speeds above 110 mph are proposed, and on two center tracks in MNCR territory; installation of high-speed (80 mph) crossovers at eight new interlocking locations (yet to be determined); installation of passing sidings or third main track at locations where potential conflicts between commuter and intercity trains are anticipated (e.g., Readville to Route 128, North Attleboro and Cranston). Increase superelevation in curves and/or lengthen spirals wherever possible for higher speed.

A long-term phased program is needed, to be carried out in conjunction with other Corridor improvements to achieve the desired level of train performance, system capacity, ride comfort, improved safety, and operational flexibility. Work would include:

Concrete ties:	All mainline intercity tracks presently without concrete ties, a total of 272 track miles, including the two center tracks on MNCR's New Haven Line between New Rochelle and New Haven.
New track/sidings:	Third track Readville-Rte. 128 passing siding at N. Attleboro and Cranston.

High speed crossovers: Eight universal crossovers between New Haven and Boston.

Line & Surface Program: Rework two high-speed tracks from New York to Boston, adding full superelevation and reworking spirals to achieve improved curve speeds.

Current Plans, Status, and Activity: Improved trackwork is in an early planning stage. There has recently been a high level of activity within Amtrak to evaluate needs and develop program priorities. No trackwork improvements are currently programmed (over and above normal maintenance). There has been some discussion of installing concrete ties and new CWR on the center two tracks (1 and 2) of the New Haven Line (New Haven - New Rochelle) to permit improved speeds and enhanced ride comfort for Amtrak intercity and Metro-North express trains. The cost and benefits have yet to be established, (requires further study). Increased superelevation and unbalanced elevation will permit higher speed in curves. Detailed study is needed to verify feasibility on a case-by-case basis. Spiral length criteria require resolution before proceeding with proposed improvements.

Brief History: Originally, under NECIP, concrete ties were to have been installed on both main tracks virtually the entire length of the Shore Line route between New Haven and Boston. Budget limitations prevented full implementation of the originally planned northend track program under NECIP. (Roughly 60% of the Corridor track between New Haven and Boston currently has concrete ties.) The trackwork project described here goes beyond what was originally planned under NECIP (e.g., high-speed crossovers and new sidings).

ROW Owner: Amtrak, CDOT, MBTA

ROW Maintenance: Amtrak, MNCR

Dispatching Responsibility: Amtrak, MNCR, MBTA

Train Operators: Amtrak, MNCR, MBTA, Conrail, P&W

Project Implementation:

(Potential) Funding Agencies/Sources: FRA, UMTA, CDOT, MBTA

Managing Organization: Amtrak, MNCR

Performing Organization: Amtrak, MNCR

Sequencing Considerations: Needs to be planned and coordinated with other railroad improvements, including electrification, signaling, and track realignment programs.

Other Construction/Logistic Considerations:

Construction-Period Operational Impacts:

Affected Parties: Amtrak, MNCR

Purpose or Intended Benefits:

Intercity Service: Improved speed, safety, ride comfort, operational flexibility and conflict avoidance.

Commuter Service: Improved speed, safety, ride comfort, operational flexibility and conflict avoidance.

Uncertainties and Issues: Extent of required trackwork program has yet to be determined. Additional study required.

Estimated Cost: A preliminary budgetary estimate was prepared by PBQD for this project: $110 million for Amtrak and MNCR trackwork excluding concrete tie program. Installation of concrete ties in all remaining high-speed tracks was estimated at an additional $110 million, segments as follows:

	Est. Cost 1991 $ (M)
Hell Gate Line (27.4 TM)	$ 12M
MNCR New Rochelle - New Haven (two center tracks - 115.6 TM)	$ 46M
New Haven - New London (50.2 TM)	$ 20M
New London - Providence (79 TM)	$ 32M
	$110M

Project: Signal System Upgrades

Project Full Name: Modification or Replacement of the Signal System to Support Electrification and Higher Speeds

Location: New York City to Boston in three segments: Hell Gate Line (MP E4 - 19.1); New Haven Line (16.3 - 71.7); and Shore Line (72.9 - 229).

Safety Considerations: Not a factor

Revenue Trains per Day:		
	Intercity:	max. 34
	Commuter:	max. 185
	Freight:	max. 5

Rehabilitation/Speed Improvement: Speed Improvement, although present system is approaching obsolescence on Shore Line and other isolated locations, and is not compatible with electrification.

Description of the Problem: The present signal systems in each of the above three segments will have to be replaced or modified to accommodate significantly higher speeds; the Shore Line signal system must also be made compatible with planned electrification and high speed (up to 150 MPH).

Proposed Solution(s): Install new signal systems between New Haven and Canton Junction; modify existing signal systems on Hell Gate Line and New Haven Line to accommodate higher speeds where track and alignment improvements allow.

Project Description: Amtrak's planned NYC-Boston electrification requires the signal system to be compatible with 25kV, 60Hz catenary. This will be accomplished by replacing the existing track circuitry with new 100Hz phase-selective track circuits. Impedance bonds must also be added to allow the flow of negative return current around the insulated joints without inhibiting the track circuit. Traffic and block information will be transmitted between locations via line circuits. Cab codes and block criteria are also proposed to be modified to permit higher speeds and the proposed future installation of high-speed (80 MPH) crossovers. New block layout and signal aspects will accommodate speeds up to 150 MPH. New interlocking diverging routes will be designed for 80 MPH. Signal system will utilize microprocessor-based track circuits and control/indication equipment. Block spacing anticipates increased train service; reverse signaling will be installed universally. Interlockings will all be remotely controlled via the Centralized Electrification and Traffic Control (CETC) Center in South Station, Boston. Metro-North's New Haven Line signal program is not intended to increase speed. Details of what modifications would be required for higher speeds have not been developed though a conceptual plan has been utilized for estimating purposes.

Current Plans, Status, and Activity: An Amtrak Shore Line signal replacement program is funded and is proceeding. No other signal improvements (for potential speed increases south of New Haven) are currently planned or programmed.

Amtrak is currently designing a new signal system for the Shore Line between New Haven and Boston to be compatible with electrification and train speeds up to 150 MPH. Metro-North is currently removing wayside signals on the New Haven Line but currently has no plans to raise speeds. Existing New Haven Line signal system could accommodate up to 100 MPH operation in some sections with three-block cab signals (assuming present MNCR stopping distance criteria, which are based on former PRR CE-205 standards). If AEM-7 locomotive braking criteria were used, the top speed could theoretically be raised 10-15 MPH, i.e., up to about 115 MPH without respacing (lengthening) blocks. To operate above 115 MPH, presumably the signal block layout would have to be modified. This could be required for a portion of the Bridgeport-New Haven segment, where 130 MPH speeds are possible. On the Hell Gate line, Amtrak currently has no plans to raise speeds or modify the present signal system.

Brief History: A new signal system was planned for the Shore Line between New Haven and Boston under NECIP, but once the decision was made to delete the electrification, much of the need to replace the signals was similarly eliminated. New signals and CETC were installed between Boston's South Station and Readville in conjunction with the Southwest Corridor Project and CETC was installed to Canton Junction under NECIP. While the bulk of the existing interlockings were modernized under NECIP, the rest of the originally planned signal work was cut back. Amtrak's current budget for Northend signals is approximately $150 million. (The FY 91 appropriation included $56 million for NYC-Boston NEC signal improvements.)

Metro-North installed the present New Haven Line signal system in the 1980s in conjunction with the new 12.5 kV-60 Hz electrification power supply system. The existing color-light wayside signals are currently being removed, converting the line to an all-cab-signal ("no wayside") system (except "go"/"no go" signals at interlockings).

ROW Owner: Amtrak/CDOT/MBTA

ROW Maintenance: Amtrak/MNCR

Dispatching Responsibility: Amtrak/MNCR

Train Operators: Amtrak/MNCR

Project Implementation: Amtrak/MNCR

(Potential) Funding Agencies/Sources: FRA, UMTA, MBTA, MTA

Managing Organization: Amtrak, MNCR

Performing Organization: Amtrak, MNCR, Contractor

Sequencing Considerations: Northern signal system conversion (and in particular, installation of reverse signaling) must precede electrification. Track realignment work should precede signal system conversion to avoid rework and to make sure block lengths will be adequate on new alignment.

Other Construction/Logistic Considerations: Work to be performed primarily at night and on weekends.

Construction-Period Operational Impacts:

Affected Parties: Amtrak, MNCR

Purpose or Intended Benefits:

Intercity Service: Allow increase in speed and operational flexibility.

Commuter Service: Allow increase in speed and operational flexibility.

Uncertainties and Issues: Program is proceeding in order to keep ahead of the planned northend electrification; however, there are many other uncertainties as regards other potential improvements (such as curve realignment projects, new high-speed interlockings, location of future sidings, etc.) that should be resolved before installing the new signal system.

Estimated Cost: The following estimates were prepared by PBQD for the various proposed signal system modifications:

	Estimated Cost 1991 $ (M)
Existing alignment w/o electrification	$66M
MNCR (three-block signals)	$ 4M
TOTAL PROGRAM 2	$70M
Add for electrification Existing alignment	$25M
TOTAL PROGRAM 3	$95M
MNCR Bridgeport-New Haven modifications for 130 MPH service	$ 5M
TOTAL PROGRAM 4 AND 5	$100M

Project: Grade Crossings

Project Full Name: Railroad-Highway and Pedestrian Grade Crossing Closure and Separation

Location: Mass (1), RI (2), CT (15)

Safety Considerations: Significant potential for accident with increasing train speeds, greater variability of train speeds

Revenue Trains per Day:

Intercity:	max. 26
Commuter:	max. 57
Freight:	max. 1

Rehabilitation/Speed Improvement: Speed Improvement; safety issue for train speeds above 100-110 MPH

Description of the Problem: As shown in the chart on the following page, nine public and eight private at-grade crossings remain on the Boston-New York corridor: one each in Massachusetts and Rhode Island, and the remainder in Connecticut. The Rhode Island crossing is scheduled for separation. All of the public crossings are highway crossings, as are six of the private crossings. There are also two private pedestrian crossings. The highest rail speed limit at a crossing at present is 100 MPH, but that crossing is scheduled for separation. The next highest, currently 95 MPH, is a private road crossing; all the others are now exposed to train speeds of 80 MPH or less.

A major corridor improvement program would potentially result in one private highway crossing having a train speed limit as high as 130 MPH, and one other, 110 MPH. Two other crossings could experience 90 MPH rail traffic; all the others will be limited to 80 MPH or lower. All would experience more than a doubling of current rail traffic. It is questionable whether train speeds above 100 MPH would be permissible through at-grade highway crossings on such a densely travelled high-speed corridor.

Proposed Solution(s): Solutions and palliative measures to be considered include, listed in descending order of effectiveness:

- Full grade separation by overpass/underpass

- Closure of the crossing at each side of ROW, with or without construction of parallel access roads to a neighboring overpass or underpass, by purchase or otherwise.

- Full automatic crossing gate protection covering all traffic lanes and sidewalks, including advance warning signs, flashing lights, and grade crossing "predictor" circuitry for constant warning time and time out provisions.

Should special circumstances preclude adequate protection, a reduced rail speed limit might be necessary.

Project Description: The only project currently programmed is the elimination of Wolf Rocks Road crossing by grade separation, now in the design phase. The remaining highway crossing with potential for 130 MPH train speeds is private, and would require closing. Eight public highway crossings could experience 80-110 MPH rail traffic. If these cannot be closed, they would warrant the most complete and sophisticated automatic warning systems available. All pedestrian crossings should be considered for separation or closure. A detailed examination of circumstances at each location is needed.

Current Plans, Status, and Activity: One high speed public highway crossing in Rhode Island is scheduled for separation; design is in progress.

Brief History: As a part of the NECIP and earlier legislation, all public grade crossings were to be eliminated from the NEC, with the exception of those in New London, CT, and others receiving a statutory exemption. The reasons for the exemption in New London are the slow speed of trains and the location of the railroad adjacent to the harbor, where underpasses are not feasible and overpasses would adversely affect the character of the community.

ROW Owner: Amtrak and MBTA

ROW Maintenance: Gates all maintained by Amtrak

Dispatching Responsibility: Amtrak

Train Operators: Amtrak

Project Implementation:

(Potential) Funding Agencies/Sources: FRA, FHWA, state highway and crossing safety programs, town highway departments, private owners

Managing Organization: Amtrak

Performing Organization: Amtrak, Contractors

Sequencing Considerations: Should follow trackwork and electrification and be coordinated with signal system

Other Construction/Logistic Considerations:

Construction-Period Operational Impacts: Minimal

Affected Parties: Motorists, rail passengers and crews, owners of nine private parcels, Amtrak, P&W

Purpose or Intended Benefits:

Intercity Service: Permit operation at speeds above 100 MPH; increase safety

Commuter Service: Increase safety (only one private crossings is in commuter territory)

Uncertainties and Issues: Provision of alternate access for individuals with private crossings

Estimated Cost: Pending the additional required examination cited above, PBQD has formulated a budgetary allowance of $10 million to grade separate the four crossings where speed would exceed 90 mph and close or separate the pedestrian crossings.

TABLE A-1. HIGHWAY AND PEDESTRIAN AT-GRADE CROSSINGS ON THE NORTHEAST CORRIDOR

City/Town	MP	Street	Current Speed Limit	Potential* Speed Limit	Protection	Hwy.	Ped.	Public	Private
Attleboro, MA	198.96	Lazy Lady Chicken Farm	95	130	--	X			X
Kingston, RI	160.30	Wolf Rocks Road	100	150	Gates**	X		X	
Stonington, CT	140.55	Palmer St.	80	110	Gates	X		X	
Stonington, CT	140.01	Gulfs Crossing	75	110	--		X		X
Stonington, CT	136.50	Cheseboro	70	80	--	X			X
Stonington, CT	136.65	Atwood (Walker)	70	80	Gates	X			X
Stonington, CT	136.70	Freeman's	70	80	Gates	X			X
Stonington, CT	134.90	Wampassac	65	90	Gates	X		X	
Mystic, CT	133.40	Latimore Point Road	70	80	--	X			X
Mystic, CT	132.30	Broadway Ext.	55	60	Gates	X		X	
Mystic, CT	131.50	School St.	70	80	Gates	X		X	
New London, CT	123.00	Gov. Winthrop Blvd.	25	35	Gates	X		X	
New London, CT	122.76	State St.	25	35	Gates	X		X	
New London, CT	122.60	[Coast Guard]	25	60	--		X		X
New London, CT	122.50	Bank St. Connector	25	60	Gates	X		X	
Waterford, CT	120.2	Miners Lane	60	80	Gates	X		X	
Old Lyme, CT	112.19	Chapman's Crossing	60	90	--	X			X
TOTALS:	17 At-Grade Highway and Pedestrian Crossings					15	3	9	9

* Potential maximum speeds based on preliminary analysis
** To be separated or closed; currently in design phase

Source: Amtrak Track Charts and Employee Timetable, Connecticut DOT, Rhode Island DOT, Site Visits

Project: Station Improvements

Project Full Name: Station Improvements for Improved Service and Access

Location: Specific stations between New York and Boston

Safety Considerations: Not a factor

Revenue Trains per Day: Intercity: Varies
Commuter: Varies
Freight: Varies

Rehabilitation/Speed Improvements: Both rehabilitation and speed improvements are identified.

Description of the Problem: (1) Trip time: Low-level platforms, which require passengers to go up or down several steps at the car door, seriously extend the dwell time of a stop. Currently all Amtrak express service stations except Route 128 have high-level platforms, but many of the other stations do not. (2) Access: Low platforms also limit access by physically disabled individuals. Recent legislation (the Americans with Disabilities Act) will require that such limitations be removed. (3) Parking: Parking facilities are not directly related to service improvements. However, inadequate capacity can seriously limit ridership, even if very desirable travel time is achieved. (4) Capacity: In the two-track territory between Boston and Providence, and potentially for commuter service east of New Haven (Shore Line East), the lengthy commuter train dwell time necessitated by low-level platforms can delay intercity trains. Thus, high level platforms at all such commuter stations would not only provide time savings and improve access for commuter service, but will also benefit intercity operations.

Proposed Solution(s): (1) and (2): Construct high-level platforms at all Amtrak stations. (3) Support and facilitate efforts to develop convenient parking facilities and direct access to local public transportation. (4) Construct high-level platforms at all commuter stations where no passing track exists.

Project Description: Construction of high-level platforms at all Amtrak stations, with platform length suitable for at least 12-car trains. Route 128 Station is the only major stop which does not now have high-level platforms. Relatively convenient for a large portion of the Boston-area population and 15 minutes closer to New York than South Station -- Route 128 is potentially the dominant stop for Boston-New York service and warrants priority.

Assurance of public transit access and adequate parking is a critical element of intercity rail service. However, this is a highly site-specific topic that cannot be treated from a broad perspective. In general, station and parking garage development will involve local governments and may attract at least partial private sector financing.

Current Plans, Status, and Activity: Construction of high-level platforms at Route 128 Station has been planned, with Amtrak and MBTA sharing the cost. (To date Amtrak has committed to paying up to $2M.) One point three million dollars is included in the Amtrak FY91 appropriation for this work, but this may not be sufficient.

Brief History: The NECIP included major station rehabilitation and new construction, but this element of the overall program was curtailed in the late '70s and early '80s leaving some stations (such as Route 128) with improvements planned but not implemented.

ROW Owner: MBTA (Route 128), Amtrak

ROW Maintenance: Amtrak

Dispatching Responsibility: Amtrak

Train Operators: Amtrak

Project Implementation: Amtrak

(Potential) Funding Agencies/Sources: FRA, UMTA

Managing Organization: Amtrak, MBTA

Performing Organization: Amtrak, Contractor

Sequencing Considerations:

Other Construction/Logistic Considerations:

Construction-Period Operational Impacts:

Affected Parties: Amtrak, MBTA, MNCR

Purpose or Intended Benefits:

Intercity Service: Reduced station dwell time and improved access for all patrons.

Commuter Service: Reduced station dwell time and improved access for all patrons; reduced line delays to through-trains.

Uncertainties and Issues: Scope of the projects remains to be determined.

Estimated Cost: MBTA has estimated the cost of proposed Route 128 Station improvements at $8 million. The cost of high-level platforms and pedestrian overpasses at Kingston, Westerly, Mystic, New London and Old Saybrook Stations has been estimated at approximately $5 million per station, all unfunded and unprogrammed.

Project: Electrification

Project Full Name: Electrification of the Northeast Corridor from New Haven, Connecticut to Boston, Massachusetts

Location: Between New Haven and South Station (MP 72 - 229)

Safety Considerations: Not a factor

Revenue Trains per Day:	Intercity:	max. 26
	Commuter:	max. 151
	Freight:	max. 4

Amtrak's *Montrealer* also runs on this line between New Haven and New London - one roundtrip per day. CDOT operates 13 trains per day between Old Saybrook and New Haven.

Rehabilitation/Speed Improvement: Speed Improvement

Description of the Problem: The NEC is electrified from New Haven to Washington, and all trains utilize 7000 HP AEM-7 or other electric locomotives for that portion of the route. In order to accommodate the unelectrified portion between New Haven and Boston, conventional diesel-electric power is used, thereby reducing the train acceleration (power-to-weight ratio) and imposing a ten-minute (or greater) delay in New Haven required while the locomotives are switched. With higher speed limits, the lower power of the diesels would be even more of a restriction.

Proposed Solution(s): Electrification of the route from New Haven to Boston.

Project Description: The current plan developed by Amtrak calls for 25 kV-60 Hz center-fed electrification of the entire route--360 track miles. (322 miles of main track, 12 miles of secondary track or sidings, and 26 miles of yard track). Constant tension catenary is to be used. The design is to be compatible with a maximum speed of 150 MPH. As envisioned by Amtrak, a single contract will be awarded for design and construction of the catenary and power supply system, which will include substations and switching stations. FRA is responsible for preparing the necessary environmental impact statement.

A significant part of the project involves providing adequate catenary clearance at the 225 overhead bridges (including three tunnels) along the route. As many as one-third of the bridges appear to provide insufficient clearance. Various means such as undercutting of track or raising of bridges will be necessary. In some locations, this may prove very costly and complex to implement.

One short segment in particular presents severe clearance constraints and will involve considerable expense to resolve. There are five low clearance bridges between Back Bay and Boston South Station that must be raised or the track beneath them lowered (or both). The area has high water table, poor drainage, and an abutting street network that will not permit any significant bridge raising. Providing adequate clearance at this location will most likely involve construction of an expensive "boat section" structure beneath the tracks to permit lowering them. Traffic must be maintained when this construction is in process.

Current Plans, Status, and Activities: Amtrak has issued a request for bids for "design and build" electrification of the route. Twenty-five million dollars is available for initial design from the FY91 appropriation; funding sufficient to implement the project remains to be provided. The Request for Quotations issued by Amtrak (response date July 8, 1991) calls for a 13-month design period and a 33-month construction phase.

In recent years estimates of the cost of electrification have been a matter of some debate, partly because of ambiguities concerning whether signalling, bridges, and other items are included.

Brief History: This project was included in early NECIP planning, but insufficient funding was available for implementation. In the early 1980s FRA undertook an electrification design effort which was 90% complete when the program was terminated; the resulting designs are available for use by firms responding to the Amtrak RFQ.

ROW Owner: MBTA in Massachusetts; Amtrak in Rhode Island and Connecticut

ROW Maintenance: Amtrak

Dispatching Responsibility: Amtrak

Train Operators: Amtrak, Conrail, P&W

Project Implementation: Amtrak

(Potential) Funding Agencies/Sources: FRA

Managing Organization: Amtrak

Performing Organization: Contractor

Sequencing Considerations: Curve realignment, rock excavation, and overhead bridge raising and/or track undercutting (required at up to 91 bridge locations for catenary clearance) should be accomplished before completing the electrification.

Other Construction/Logistic Considerations: Work requiring track outages will all be performed at night. It is planned that contractor track occupancy will be limited to no more than two block lengths at any time. Those blocks must be on different tracks and be separated by two unoccupied block lengths. Installation of reverse signalling will minimize effect of track outages.

Start of construction is dependent on the EIS process (Record of Decision) being conducted by FRA.

Construction-Period Operational Impacts: Impact to operations will be minimal.

Affected Parties: Amtrak, MBTA, CDOT, P&W

Purpose or Intended Benefits:

Intercity Service: Shorter trip times can be achieved due to the higher acceleration capability and top speed of electric motive power and the elimination of the engine change at New Haven. In addition, electrification would facilitate true run-through operation between Boston and Washington, minimizing turning of trains at Pennsylvania Station, which is costly in terms of platform and tunnel "slots." Electrification also provides benefits to all classes of service, including multistop lower speed operations. Amtrak foresees operating and maintenance advantages to electric vs. diesel or turbine locomotives.

Commuter Service: Commuter trains could benefit from electrification if funds were available to repower commuter trains with electric motive power and if the power supply system were sized adequately to accommodate the added traffic. Current electrification plans do not provide for either of these added-cost items.

Principal Beneficiary: Intercity service is the principal beneficiary; there would be significant commuter benefit only if MBTA is able to move to electrified commuter services.

Uncertainties and Issues: P&W, which has significant traffic for high and wide loads, has expressed strong concern over potential clearance limitations.

Estimated Cost: Construction of full two-track 25 kV electrification system from New Haven to Boston, including additional third track, yard tracks and eight new universal, high-speed interlockings is estimated by PBQD at $370M, determined as follows:

Construction Cost, Base	$274M
Contingencies, 10%	27
Total	$301M
Engineering and Design, 10%	30
Construction Mgmt., 8%	24
Agency and Admin., 5%	15
Total Estimated Cost	$370M

It is estimated that an additional $100M is required to obtain the vertical clearance envelope at overhead bridges. Eighteen million dollars is included in this estimate for Back Bay - Boston South Station bridges. Amtrak's estimate for the northend electrification design/build construction contract is $225 million (excluding vertical clearance attainment).

Project: Curve Realignments

Project Full Name: Reduction or Removal of Curvature-Based Speed Restrictions

Location: Throughout New York-Boston Route

Safety Considerations: The safety of present operations over existing curvature is not a factor; however, there are safety criteria requiring analysis in order to raise curve speeds by simultaneously increasing superelevation to 6 inches and curve unbalance to 6 inches.

Revenue Trains per Day:	Intercity:	max. 26
	Commuter:	max. 57
	Freight:	max. 4

Rehabilitation/Speed Improvement: Speed Improvement

Description of the Problem: Train speed (and therefore travel time) is fundamentally limited by the horizontal and vertical curvature present in the alignment, regardless of the power rating, method of propulsion and speed capability of the trains on the line. The Northeast Corridor includes more than 200 curves, many of which exceed 2 degrees of curvature, and this situation is the most severe constraint on trip time.

Proposed Solution(s): There are three levels of fixed-plant improvements to reduce the speed constraints associated with curves:

(1) Implementation of maximum superelevation consistent with Federal regulations and passenger comfort, for a particular track alignment;

(2) Changes in horizontal and vertical alignment which can be accomplished within the existing right-of-way (varying in width from approx. 80 feet to 250 feet on the NEC);

(3) Changes in horizontal and vertical alignment which require acquisition of land outside the existing right-of-way.

[A fourth possibility, acquisition of a new alignment segment, is treated separately. See the project entitled "Bypass Alignment."]

In conjunction with the above, existing criteria for spiral transitions to curves, superelevation, and allowable curve unbalance require further study, for both freight and passenger equipment applications.

Project Description: As part of the VNTSC/NEC study, an analysis has been undertaken to examine the feasibility and speed improvements of implementing maximum superelevation and seeking to reduce curvature wherever practical in the NY-Boston portion of the NEC. Though listed here as a single project, the improvement effort would actually consist of a large number of separate "subprojects" at individual curves between Boston and New York. The initial analysis represents a "best case"; it is likely that detailed study would reveal limitations in some cases as to what can be accomplished for reasonable investment.

The subprojects identified in the analysis increase track superelevation on existing alignment; shift track alignment horizontally within the ROW for a number of curves; and shift track alignment horizontally outside the ROW for a lesser number of curves. These alignment changes permit the achievement of higher speeds which can be sustained for meaningful periods. The details of the analysis, which can serve as a starting point for specific in-depth studies, are presented in Appendix D.

Attainment of the speeds suggested in the analysis conducted for this study depends upon establishing unequivocally that neither safety nor passenger comfort is compromised by relatively high (6") superelevation and unbalance, or cant deficiency. This will undoubtedly require extensive testing and analysis, and may be suitable only for more-sophisticated types of railcar suspension technology. It is also likely that detailed design studies will reveal that in some cases it is not possible to provide satisfactory transition into the curve for use of the high assumed speeds.

The benefits of curve realignment come in small increments. Many small "subprojects" would be undertaken. Even within the ROW, implementation implies significant disruption and expense with only small benefits for each curve treated. Making improvements of this nature is only likely to be warranted in the context of an overall program directed toward significant trip time reduction.

Increasing line speed tends to increase train separation, raising a line capacity issue which must be addressed through signal system design and scheduling and dispatching policy. More important, in commuter rail territory there will be a need to operate commuter trains at near to the intercity speed during peak periods, which will require close coordination and cooperation between the affected railroads.

Environmental impact is a concern with regard to curve realignments outside of existing ROW. However, many of these are in relatively rural areas. Benefits in addition to speed are possible. There may be opportunities to eliminate existing narrow right-angle grade-separated crossings of parallel roadways. Realignment could in some cases release more land than is now utilized for rail purposes (negative net loss), while at the same time increasing the value of the public investment in and benefit from the rail infrastructure.

Current Plans, Status, and Activity: Initial analysis has defined potential improvements; detailed layout of realignments and assessment of feasibility would be the next logical step. No program currently exists. Technical criteria require further study.

Brief History: The existing NY-Boston rail alignment was built in the 1840s, but improved in the late 1800s and early 1900s. The Boston-area Southwest Corridor project produced a realignment which raised speeds as a part of NECIP. The new Providence Station also resulted in alignment shifts as a part of NECIP.

In addition, a broad program of major and minor realignments was defined in the mid-1970s as part of NECIP, but almost all of these were dropped due to funding limitations. Those proposed realignments were generally focused on achieving a 150-mph capability, whereas the present examination focuses primarily on a more modest, but more readily achievable, 125-mph capability, with portions of ROW capable of 150 mph.

ROW Owner: Amtrak, MTA, CDOT, MBTA

ROW Maintenance: Amtrak, MNCR

Dispatching Responsibility: Amtrak, MNCR

Train Operators: Amtrak, MNCR, P&W, CR

Project Implementation:

(Potential) Funding Agencies/Sources: FRA, UMTA, CDOT, RIDOT

Managing Organization: MBTA, Amtrak, MNCR, CDOT

Performing Organization: Amtrak, MNCR, contractor support

Sequencing Considerations:

Other Construction/Logistic Considerations:

Construction-Period Operational Impacts: Connection of off-ROW segments requires off-peak temporary halt of operations on one track at a time.

Affected Parties: Amtrak, CDOT, MNCR, RIDOT, MBTA

Purpose or Intended Benefits:

Intercity Service: Potential trip time reductions for all proposed realignments combined totals over 12 minutes for the most aggressive high-speed trains (e.g., TGV, etc.)

Commuter Service: No curve significant realignments are proposed in commuter territory.

Principal Beneficiary: Intercity service

Uncertainties and Issues: Standards for cant deficiency (unbalance) and spiral transitions between curves and tangent track need to be reviewed in order to maximize speed improvements achievable through increases in superelevation. Vehicle types must be tested for operating at up to 6 inches unbalance. Analysis of each curve must proceed on a case-by-case basis.

Estimated Cost: A total of 34 realignment projects has been analyzed. Each of these projects consists of between one and six curves which would be realigned as a cluster to achieve meaningful reductions in trip time, at costs ranging from $0.5 million to $88 million per project cluster. One realignment project is unique, consisting of 11 curves realigned on a principally new alignment over 18 miles between Westerly and Kingston, RI, estimated to cost $262 million.

Twenty-seven realignment projects have been included in Program 4 - All Speed Improvements. They reduce trip times by almost 11 minutes for existing equipment, at a projected cost of $715 million.

Appendix D, Curve Realignment, provides detailed information on the methodology of analysis and discussion of important assumptions behind the work. It also describes the individual curve improvements included in the NEC improvement programs.

Project: Bypass Alignment

Project Full Name: New Alignment between Old Saybrook, CT and Bradford Jct., RI Bypassing Shore Line

Location: Shore Line MP 105.1 (Old Saybrook)
Shore Line MP 145.4 (Bradford Jct.)

Safety Considerations: Not a factor

Revenue Trains per Day:

	Intercity:	26
	Commuter:	TBD
	Freight:	TBD

Rehabilitation/Speed Improvement: Speed Improvement

Description of the Problem: The Shore Line alignment between Old Saybrook, CT and the Connecticut/Rhode Island state line contains the most restrictive series of curves on the Corridor, as well as five movable bridges over the Connecticut River, Niantic River, Shaw's Cove, Thames River, and Mystic River. While much of the alignment is rural and lends itself to curve realignment projects, achieving meaningful 150-mph stretches in this territory is precluded by various "hard spots" (such as the movable bridges), and 100 to 110 mph maximum speeds are the best that can be obtained reasonably. The movable bridges require substantial expenditures for rehabilitation/replacement at present, and are a source of ongoing maintenance requirements and operating delays.

Proposed Solution(s): A new alignment between Old Saybrook, CT and Bradford Jct., RI, coupled with certain curve realignments on the existing NY-Boston alignment elsewhere, has been proposed by Amtrak.

Project Description: The bypass alignment would begin at Old Saybrook, CT, would be inland of the Shore Line alignment, and would utilize existing highway alignments to the maximum extent feasible. The new alignment would cross waterways on high fixed bridges not requiring movable spans. Because of the substantially reduced curvature, the alignment would permit 150-mph operation throughout its length, and would be approximately 4 miles shorter in length. At Bradford, RI (just East of Westerly) the route would rejoin the existing Shore Line, where curve realignments (described separately) would allow 150-mph speeds to be maintained for an additional 25 miles, approximately.

Summary of Status and Issues: No activity planned at present. Amtrak has an internal study including an environmental assessment, engineering assessment and conceptual cost estimate.

Brief History: Amtrak initiated this project during 1990.

ROW Owner: Amtrak

ROW Maintenance: Amtrak

Dispatching Responsibility: Amtrak

Train Operators: Amtrak

Project Implementation:

Funding: Unresolved
Manager: Amtrak
Performing Organization: Amtrak and Contractors

Sequencing: Decision on bypass should be reached prior to expenditure on Shore Line for curve realignments and movable bridge replacement (Niantic and Thames River Bridges), and electrification between Old Saybrook and Bradford Jct.

Affected Parties: Amtrak

Purpose or Intended Benefits:

Intercity Service: Reduces travel time on segment by about 10.6 minutes. Permits consolidation of existing antiquated stations at New London, Mystic, and Westerly into a new modern regional station at New London-Mystic.

Commuter Service: None

Principal Beneficiary: Intercity

Uncertainties and Issues: Cost; lengthy environmental, permitting, approval, and construction process; disposition of existing Shore Line.

Estimated Cost: Based on preliminary cost estimates, the bypass alignment project would require an incremental cost of $860M over the Program 4 costs. This incremental cost reflects the savings from curve realignment projects P19 through P29 (see Appendix D) which would not be implemented, as well as the rehabilitation/replacement costs of Niantic and Thames River movable bridges. Electrification and signaling costs are assumed to be unaffected by the Bypass Alignment; i.e., the costs are comparable for the Shoreline and the new route. No adjustment in the Bypass Alignment estimate was made for lower fixed bridge or track program costs, since these are relatively minor and may be incurred anyway before a decision is reached on the Bypass.

BYPASS COST ESTIMATE	1991 $, in Millions
Base Estimate (proposed Amtrak Alignment A-2)	1,093
Less savings from overlap on Program 4: Bradford Jct. to E. Greenwich	(154)

	939

Engineering/CM/Project Control	108
Amtrak Admin	40
Amtrak Force Account	2

Subtotal	1,089
Contingency at 20%	218

Total Bypass Cost	1,307
Less Elec. and Signal	(126)
Subtotal (shown in Alt. Program 5)	1,181
Less Curve Realign. Proj. eliminated from Program 4	(267)

Subtotal	914
Less Bypassed Movable Bridges (Niantic, Thames)	(54)

Net Added Cost of Bypass	860

APPENDIX B

TRAIN PERFORMANCE CALCULATIONS

INTRODUCTION

A Train Performance Calculator (TPC) is a computer program which simulates the operation of a train over a railway route. It has become a useful tool for many of the larger railroads, most of which have developed simulators to suit their own needs and computer system capabilities. The TPC in use at the Volpe National Transportation Systems Center (VNTSC) of the U.S. Department of Transportation was originally developed by the Missouri Pacific Railroad for internal use. It was purchased by VNTSC and modified to expand its capabilities, particularly for passenger train operations. To enhance its portability and usefulness, the program has now been adapted to run on commonly available microcomputers.

The purpose of a Train Performance Calculator is to predict or replicate the movement of a train along a given track. The results of such a program are contained in tables or graphs that show the speed, time, distance, energy or fuel consumption, and throttle positions as the train moves along the route. The potential uses of a TPC include determination of the following information for a specific train and route:

- Run time
- Motive power necessary to make a run in a given amount of time
- The effect of changing the number of locomotives
- The effect of a track relocation or reconstruction (which eliminates or reduces grades or curves) upon the operating speeds, motive power requirements, and energy consumption.
- The effect of eliminating or introducing a speed restriction or station stop.

GENERAL CHARACTERISTICS OF A TPC

In order to simulate the running of a train, the TPC needs information about the route and about the train. The TPC must have a description of the track over which to run the train. A set of values describing the characteristics of a point on the track constitutes one record of track data. A group of records, usually beginning at one station and ending at another (not necessarily the next), constitutes a route segment. The TPC will link together a number of such segments and run a train with or without stops from one end to the other.

When the route has been described, information about the train is needed in order to run it over the route. The length and type of cars in the train determine the aerodynamic forces acting on them.

The locomotive characteristics required are the data on tractive effort capabilities and the fuel or energy rates when idling and running.

When a route and a train have been described, the TPC can run a train over the route. The fundamental mathematical model for train movement is based on simple Newtonian laws of motion. The forces involved are those due to train resistance, locomotive tractive effort, and braking. Train resistance is made up of a number of components: rolling friction, bearing friction, flange friction, and aerodynamic resistance, which is proportional to the square of the velocity. The total resistance force is calculated using the "Davis Equation," which is based on extensive research over many years.

The power required to overcome the force is proportional to the product of that force and the velocity. Therefore, the locomotive horsepower required to pull a given aerodynamic shape at appreciable speed will tend to be proportional to the cube of the velocity.

Tractive effort is the force which a locomotive exerts at the driving wheels to move itself and its trailing consist. It is limited by the power available from the traction motors, by the velocity, and by the adhesion characteristics of the wheel-rail interface.

When the train needs to be slowed because of a speed restriction or station stop, brakes are applied. This results in a retarding force at the wheel-rail interface of all locomotives and cars in the train which is adhesion limited but which acts as an additional resisting force. The force applied is a function of brake system parameters, time, velocity, and weight of lading.

If the forces due to train resistance, tractive effort, and braking are in balance, the train will remain at constant velocity. However, if they are unbalanced, there will be an acceleration (or deceleration) resulting from the familiar $F=m*a$ of Newton. The acceleration will be equal to the algebraic sum of the forces divided by the mass of the train.

A simplified explanation of the basic iterative procedure by which the performance calculations are made is as follows. The TPC compares the present train speed to the speed limit. If tractive effort is available in excess of the train resistance, it will be applied subject to the adhesion limit. The velocity will be incremented and the time and distance to achieve the velocity change will be calculated and incremented. The user has the ability to override the default velocity increment of 1.0 mile per hour. If the train is already at speed limit, then the distance is increased by 528 feet and the new time is calculated.
The TPC looks ahead 30 track records for speed limit reductions and calculates the distance required for braking in advance. When that point is reached, the brakes are applied. Once deceleration is called for, the velocity will be decremented and the time and distance to achieve the change will be calculated and incremented.

The model requires the train to attempt to accelerate to and run at the speed limit whenever possible.

The user has a choice of Summary or Detail Printout. The Summary Printout contains a line only at stations along the route and includes only location, time, speed, and energy information. The Detail Printout contains a line every time the speed changes by one mile per hour or the distance is incremented by one mile. A Throttle Position Summary, Velocity Range Summary, and Energy Use Summary are available as options.

Comparisons of simulation results with actual performance have shown that the simulator reproduces the movement of the train with reasonable accuracy. Results should be thought of as an estimate of the minimum running time over the selected section of track for a train with the specified motive power and consist characteristics and considering the speed restrictions and stops imposed. Normal stopping times for inspections and crew changes are not usually included in the prepared track data and the TPC does not automatically include the random delays such as meets and mechanical failures. When applying the simulator to scheduling applications, additional time should be allowed for these delays.

The following pages show an example of the type of route data used (the example is for the speed limits in the fall of 1990) and a typical output summary for a run assuming Program 3, with full electrification. The output sample shows raw TPC time, without the added 1 minute adjustment to allow for the optimism inherent in the assumption of 6-inch unbalance, and not including the 5% pad. These modifications yield a schedule time of 2:52, compared to the TPC time of 2:42. (See discussion in Section 4.)

A chart is also provided which shows the employee timetable speed limits between New York and Boston.

TABLE B-1. SAMPLE NEC TRACK DATA - 1990 TIME TABLE SPEEDS

0.00	228.8	Boston, MA		0.00	15
0.05	228.7	S. Sta, Boston			15
0.10	0.0				15
0.20	228.6				15
0.35	228.4	Cv 1	11.000		15
0.52	228.3	Cv 2(2V)	0.633		15
0.66	0.0		0.633		15
0.70	228.1	COVE	-3.667	2.80	30
0.84	228.0				30
0.91	227.9	Cv 5(8)	-3.450		30
0.96	227.8		-3.450		30
1.01	227.7				30
1.11	0.0	Cv (7)	-0.667		30
1.20	227.6	Back Bay Sta	-0.667		30
1.24	0.0				30
1.27	227.5	Cv 6(6)	-9.917		30
1.41	227.4				30
1.51	0.0				30
1.72	227.1			2.04	100
2.13	226.7				100
2.33	226.5	Ruggles St.			100
2.54	0.0				100
2.65	226.1	Cv 9(5)	-1.000		100
3.06	225.7		-1.000		100
3.14	225.6		-1.000		100
3.24	225.5	Cv 10(4)	1.250		100
3.64	225.2				100
3.66	225.1	Cv 11(3)	-1.033		100
3.78	225.0		-1.033		100
3.90	224.9		-1.033		100
3.99	224.8				100
4.09	224.7	Cv 12(2)	0.917		100
4.18	224.6		0.917		100
4.29	0.0		0.917		100
4.34	224.5		0.917		100
4.74	224.1		0.917		100
4.79	224.0				100
4.89	223.9				100
4.94	0.0	Cv 12a(1)	0.217		100
5.05	223.7	Forest Hills	0.217		100
5.09	0.0				100
5.40	223.4	Cv 13A	-1.000		100
5.51	0.0		-1.000		100
5.67	223.1		-1.000		100
5.89	222.9		-1.000		100
5.94	222.8	Cv 13B	-0.333		100
6.19	222.6				100
6.29	222.5				100
6.44	222.3	Cv 14	1.000		100
6.64	222.1				100
6.74	0.0				100
7.79	221.0				100
8.09	220.7	Cv 15	1.083		100
8.34	220.4				100
9.45	219.3				100
9.62	219.2	Readville			100
9.64	219.1	Cv (16B)	0.217		100
9.74	0.0				100
9.79	219.0	Cv (16A)	-0.317		100
9.90	218.9				100
10.29	218.5	Transfer		5.14	95
10.61	218.2				95
11.61	217.3	Platform		0.83	60
11.71	217.2	Route 128 Sta			60
	217.2	Route 128 Sta			60
0.10	217.1	end of platform		11.51	95
0.16	217.0	Milepost 217			95
0.43	216.7				95
1.06	216.1	Cv 16	-1.000		95
1.43	215.7		-1.000		95
1.61	215.6				95
1.78	215.4				95
2.12	215.0				95
3.31	213.8	Canton Jct. Sta		2.03	80
3.36	0.0	Cv 17	1.000		80
3.44	213.7	viaduct SO	1.000		80
4.16	213.0	end SO		0.64	95
4.46	212.7	Cv 18	0.950		95
4.71	212.5				95
5.61	211.6	Cv 19	-1.000		95
5.81	211.4				95
6.41	210.8	Cv 20	-1.000		95
6.49	210.7	Sharon	-1.000		95
6.66	210.5				95
7.01	210.1	Cv 21	-0.950		95
7.16	210.0		-0.950		95
7.51	209.7				95
7.79	209.4				95
8.16	209.0	Milepost 209			95
8.64	208.5				95
10.16	207.0	Cv 22	1.083		95
10.56	206.6				95
10.96	206.2	E. Foxborough			95
11.29	205.9				95
11.91	205.2	Cv 23	0.917		95
12.16	205.0			5.05	100
12.30	204.9				100
12.78	204.4				100
13.23	203.9	Mansfield			100
14.04	203.1				100
14.35	202.8				100
14.99	202.2				100
16.53	200.6				100
17.16	200.0	Milepost 200		3.00	95
17.76	199.4	#20 TO diverge			95
17.96	199.2	Diverge sig			95
18.21	198.9				95
18.96	198.2				95
19.43	197.7				95
19.66	197.5				95
20.04	197.1				95
20.26	196.9	Attleboro			95
20.32	196.8				95
20.69	196.5				95
20.94	196.2				95
21.08	196.1	End diverge			95
22.16	195.0			3.16	100
22.66	194.5	Cv 24	1.450	0.30	95
22.86	194.3		1.450		95
23.36	193.8			0.44	100
23.46	193.7	Hebronville			100
24.16	193.0				100
24.73	192.4				100
25.34	191.8				100
25.44	191.7	S. Attleboro			100
26.38	190.8	State Line			100
26.48	190.7				100
26.66	190.5	Cv 25A	-2.917	1.98	55
26.73	190.4		-2.917		55
26.82	190.3	Blackstone R.	-0.867		55
26.86	0.0	Cv 26A	-2.817		55
26.96	190.2	Cv 26B	-4.200		55
27.16	190.0		-4.200		55
27.26	189.9				55
27.46	189.7	Cv 27	3.283		55
27.59	189.6	Pawtucket	3.283		55
27.61	189.5		3.283		55
27.86	189.3			1.31	70
28.24	0.0				70
28.26	188.9	Cv 28	-4.333	0.34	55
28.46	188.7			0.22	70
28.61	188.6	LAWN	-0.750		70
28.66	188.5				70
28.76	0.0	Cv 30	0.500		70
28.81	0.0				70
29.24	188.0	Cv 31	-1.000		70

TABLE B-2. RUN SUMMARY

Run 3: Electric passenger train
From S. Sta, Boston to NY
Penn Station; Program 3 Improvements
Power consist beginning at S. Sta, Boston
1 Electric unit: AEM7
Train consist beginning at S. Sta, Boston
6 cars total.

Elapsed time running:	2:37:18	Average running speed	88.25 mph.
stopped:	0:05:00	Total miles: 231.36	
	--------		
total:	2:42:18	Average overall speed	85.53 mph.

STATION	TIMETABLE CLOCK TIME HRS:MIN				ELAPSED TIME HRS:MIN				PASSING SPEED	TIME STOPPED
S. Sta, Boston			LV	0:00			LV	0:00	0	
Back Bay Sta	AR	0:02	LV	0:03	AR	0:02	LV	0:03		0:01:15
Forest Hills			LV	0:06			LV	0:06	112	
Readville			LV	0:09			LV	0:09	128	
Route 128 Sta	AR	0:10	LV	0:11	AR	0:10	LV	0:11		0:01:15
Canton Jct. Sta			LV	0:14			LV	0:14	107	
Mansfield			LV	0:19			LV	0:19	130	
Attleboro			LV	0:23			LV	0:23	130	
LAWN			LV	0:28			LV	0:28	60	
Providence, RI	AR	0:31	LV	0:32	AR	0:31	LV	0:32		0:01:15
CRANSTON			LV	0:36			LV	0:36	74	
Davisville			LV	0:43			LV	0:43	128	
Kingston, RI			LV	0:48			LV	0:48	130	
Westerly, RI			LV	0:58			LV	0:58	90	
Mystic, CT			LV	1:04			LV	1:04	60	
Mystic River Br			LV	1:04			LV	1:04	60	
Groton, CT			LV	1:10			LV	1:10	60	
New London, CT			LV	1:12			LV	1:12	35	
NAN			LV	1:17			LV	1:17	83	
CONN			LV	1:24			LV	1:24	89	
Old Saybrook			LV	1:25			LV	1:25	94	
Guilford			LV	1:35			LV	1:35	124	
Branford			LV	1:40			LV	1:40	65	
New Haven, CT	AR	1:47	LV	1:48	AR	1:47	LV	1:48		0:01:15
DEVON			LV	1:56			LV	1:56	117	
Bridgeport, CT			LV	1:59			LV	1:59	68	
BURR RD			LV	2:01			LV	2:01	91	
WALK			LV	2:08			LV	2:08	75	
Stamford, CT			LV	2:14			LV	2:14	95	
GREEN			LV	2:16			LV	2:16	100	
PIKE			LV	2:20			LV	2:20	87	
New Rochelle			LV	2:24			LV	2:24	50	
SHELL			LV	2:25			LV	2:25	50	
PELHAM BAY I/L			LV	2:28			LV	2:28	75	
GATE			LV	2:36			LV	2:36	70	
HAROLD			LV	2:37			LV	2:37	70	
NY Penn Station	AR	2:42			AR	2:42				

ELAPSED TIME IN EACH THROTTLE POSITION

THROTTLE POSITION	% OF RATED H.P. AVAILABLE	ELAPSED TIME	% OF TOTAL TIME	ENERGY USED
BRAKE	0.	0 hr 17.41 min	10.72%	64.98 kwh
1	0.- 5.	0 hr 16.43 min	10.12%	91.17 kwh
2	5.- 12.	0 hr 14.02 min	8.64%	177.50 kwh
3	12.- 31.	0 hr 28.29 min	17.43%	789.49 kwh
4	31.- 46.	0 hr 17.17 min	10.58%	785.54 kwh
5	46.- 59.	0 hr 2.57 min	1.58%	159.47 kwh
6	59.- 74.	0 hr 21.30 min	13.12%	1677.29 kwh
7	74.- 89.	0 hr 27.95 min	17.22%	2640.76 kwh
8	89.-100.	0 hr 12.18 min	7.50%	1323.00 kwh
IDLE	0.	0 hr 5.00 min	3.08%	18.68 kwh
TOTAL		2 hr 42.31 min	100.00%	7727.87 kwh

ELAPSED TIME IN EACH VELOCITY RANGE

VELOCITY RANGE	ELAPSED TIME	% OF TOTAL TIME	ENERGY USED
0 - 10 mph	0 hr 6.16 min	3.80%	30.30 kwh
11 - 20 mph	0 hr 3.19 min	1.96%	43.44 kwh
21 - 30 mph	0 hr 1.84 min	1.14%	44.00 kwh
31 - 40 mph	0 hr 2.90 min	1.79%	74.19 kwh
41 - 50 mph	0 hr 6.95 min	4.29%	146.10 kwh
51 - 60 mph	0 hr 9.84 min	6.06%	280.85 kwh
61 - 70 mph	0 hr 14.13 min	8.71%	446.69 kwh
71 - 80 mph	0 hr 18.15 min	11.18%	837.61 kwh
81 - 90 mph	0 hr 25.47 min	15.69%	1186.59 kwh
91 - 100 mph	0 hr 23.75 min	14.63%	1378.54 kwh
101 - 110 mph	0 hr 18.81 min	11.59%	1216.83 kwh
111 - 120 mph	0 hr 12.29 min	7.57%	894.25 kwh
121 - 130 mph	0 hr 18.81 min	11.59%	1148.49 kwh
TOTAL	2 hr 42.31 min	100.00%	7727.87 kwh

APPENDIX C. FACTORS AFFECTING SPEED

INTRODUCTION

Assessment of means of reducing the scheduled rail travel time between New York and Boston naturally begins with consideration of the system elements which can constrain operating speed. In order to provide some perspective on the improvement projects examined in this study, the major factors affecting speed on the Corridor are indicated below.

TRACK STRUCTURE

The Federal Railroad Administration has issued standards which define the maximum speed at which trains can be operated for various classes of track defined by physical characteristics. The highest speed allowed by these standards is 110 MPH for passenger service (Class 6 track). Higher speeds can be used based on waivers issued for specific locations; sections of the Corridor between New York and Washington have been waivered to 125 MPH. Given that substantially greater speeds are in use elsewhere in the world, with no evident safety problem, it has generally been assumed that limits above 125 MPH could be applied with appropriate construction and inspection standards. At present, the highest speed used on the north end of the Corridor is 110 MPH, and that only for a few short segments.

In addition to compliance with appropriate safety standards, speeds may be further limited by considerations of ride quality and passenger comfort. Further, the higher cost of track maintenance, particularly for high superelevation on curves, may make attainment of maximum speed economically unattractive.

TRACK CURVATURE

On average, the route between Boston and New York includes more than one curve per mile. Curvature is significantly more of a limit on that route than on New York-Washington segment. These curves, many greater than two degrees, represent a critical impediment to high speeds.

Just as for other surface modes, curves are often banked to permit higher speed than would otherwise be suitable. In railroad terminology, the distance by which the outer rail is elevated above the level of the inner rail is called "superelevation", typically measured in inches. The "balance speed" for a curve is the speed at which the centrifugal force is exactly balanced by the inward component of gravitational force associated with the superelevation. Federal regulations permit trains to operate at a speed that would be balanced if there were three additional inches of superelevation; this condition is commonly referred to by several equivalent terms: "3 inches of unbalance," "3-inch underbalance," or "3-inch cant deficiency." The FRA can approve operations above

3 inches of unbalance, and has granted waivers for 4-inch and 5-inch unbalance at some locations between New Haven and Boston.

In some countries, high-speed service is operated at unbalance exceeding 8 inches. Many experts feel that with sufficiently stringent track standards and suitable rolling stock, use of 6-inch unbalance for curves with 6" superelevation (thus permitting speeds equal to the balance speed for 12" superelevation) may be fully acceptable in terms of safety and passenger comfort. Refinement of these standards and determination of curve speeds for which waivers can be approved on the NEC would be part of any improvement program.

For the purposes of this study, the upper limit on curve speeds, when track quality permits and other constraining factors are not present, will be based on 6-inch superelevation and 6-inch unbalance, for a total of 12 inches. Factors which can reduce this limit in practice include catenary condition, distance available for spiral transition from tangent track into the curve, proximity of station platforms, and spacing between tracks. It is further assumed in this analysis that tilt-suspension coaches could operate at 8-inch unbalance, or 14 inches including the superelevation, a result consistent with prior limited testing but subject to extensive future testing and analysis to establish acceptability. These values are used, however, only in assessing fixed plant improvements that would yield suitable civil track speeds.

In addition to questions of superelevation and allowed unbalance (discussed in Section 3), curve speed is sometimes limited by the absence of an adequate transition region from the straight ("tangent") track into the curve. If there is not a sufficiently long spiral section during which the superelevation is gradually increased and the curve initiated, passengers can be subjected to a sudden sideways impulse which could be hazardous to individuals standing or walking, particularly between cars. The Corridor track was not initially designed for high speeds, and the lack of adequate distance of spiral limits some curves to speeds well below the values determined only from unbalance and superelevation.

Other factors which can reduce speed in curves below the theoretical maximum include close track centers (inadequate clearance with trains on parallel tracks) and station platforms or other structures which preclude banking or tilting.

CATENARY

On an electrified railroad, as exists between New Haven and New York City, the interaction between the rail vehicle pantograph and the catenary which provides power is complex and critical. Although design of catenary suitable to very high speeds is well understood, the system actually in place on the Corridor has outlived its useful service life and has deteriorated to the point that speeds are limited to 90 MPH at best, and are further lowered during periods of excessively high and low temperatures, due to the consequences of associated contraction and expansion.

BRIDGES

The NEC includes many fixed and movable bridges for which the tracks are rigidly attached to the bridge, rather than riding on conventional track ballast. At high speeds this produces a rough ride, which leads to a passenger-comfort restriction on maximum speed over the bridge. Movable spans offer an additional constraint: the rail joints between the fixed and movable portion of the tracks. These joints must be able to accommodate significant thermal contraction and expansion, and are naturally critical to safe operation as well as ride quality. NEC bridge speeds are limited by these existing joints in several locations.

GRADE CROSSINGS

Wherever highways or pedestrian paths cross railroads at grade, there is the potential for serious accidents. With high-speed rail operations, the possibility of death and injury to rail passengers is added to the risk. No formal Federal standards exist, but typically public agencies and affected communities are unlikely to accept rail operation over at-grade highway crossing at speeds greater than 100 to 110 MPH, even with automatic gates, flashing lights and a bell to warn vehicle operators. Where crossing closure or separation is not feasible, the maximum authorized speed for trains could be restricted because of the presence of one or more crossings.

Although many crossings were eliminated in the Northeast Corridor Improvement Project and through independent efforts, there remain 15 highway at-grade crossings (one of which is planned for separation) and two pedestrian crossings on the NEC--all between Attleboro, Massachusetts and Old Lyme, Connecticut.

SIGNAL SYSTEM

The basic purpose of the railroad signal system is to assure safe separation of trains. The maximum safe speed for a given signal system depends on the assumptions made concerning train braking capability, the length of the signal blocks, and the number of different signal aspects which can be displayed. In addition, Federal regulations preclude operation above 79 MPH without cab signals. Fixed plant changes to permit faster travel must include modification to the signal system consistent with the maximum speed the track can support.

ROLLING STOCK

In addition to equipment that has a suspension system and sufficient motive power to attain the maximum track speed, the ability of a train to accelerate rapidly to the speed limit, whether from a slower segment or a station stop, is important in attaining a short trip time. Train Performance Calculator results indicate that a power-to-weight ratio of at least 7 to 10 HP/ton is needed for reasonable performance, with 15-20 HP/ton necessary to approach minimum practical running times on the Northeast Corridor with speed limits in the range of 100-120 MPH. (With one diesel-electric locomotive, the New England Express has a ratio of about 7 HP/ton; with an AEM-7 it exceeds 15 HP/ton.) If speed limits are higher, benefits accrue to still greater power-to-weight.

OPERATIONAL FACTORS

Station Stops

Station stops typically involve a platform dwell time of more than a minute--significantly longer if the platform is at ground level. The process of decelerating to the stop and accelerating back to a high cruising speed will typically add several minutes to the trip time. Thus, the gain local passengers get from a stop must be balanced against the loss of overall ridership due to greater trip duration.

Traffic

Rail traffic can be a significant constraint. The signal system will enforce a substantial separation between trains, and any attempt to close the gap will result in restrictive signals and required speed reductions. Thus, if commuter trains are operating for substantial distances at lower speeds than the Amtrak trains, the intercity unit will be delayed. If trackage is adequate, and opposing traffic permits, overtaking may be possible, but if the intercity train has to change tracks, the turnout will often limit speed. Thus, in areas with heavy commuter rail traffic, the commuter train maximum speeds will necessarily also become the intercity limits when operations are near capacity.

If rail lines merge--as happens in New Rochelle, where Amtrak's Hell Gate Line joins the Metro-North New Haven line--an intercity train which misses its "slot" for the move will be delayed just like an automobile seeking to merge from a "yield" sign onto a crowded high-speed highway and having to wait for an empty space. Further, an Amtrak which has missed its slot may then have to follow a slower commuter train, so the delay will be compounded.

Reliability and "Pad"

Running time cannot be predicted precisely. Locomotive power can vary, train operators may differ from one another in their ability to follow speed limits precisely, and delays can easily occur at station stops. The less precision there is in railroad operations, or the less the railroad can control circumstances, the more it is necessary to allow extra time in the schedule--"pad"--so that riders will at least have predictable service and on-time performance records will be respectable. Thus, uncontrollable sources of variability, even if they cause delays only occasionally, will increase the pad and may thereby slow all trains, depending on where the pad is placed in the schedule. Of even greater concern are major delays, which generate a perception by passengers of unreliability and seriously diminish the value of nominal schedule improvements. An example which occurs on the Corridor is that of an Amtrak train's missing its slot in Metro-North territory, as described above.

APPENDIX D. CURVE REALIGNMENTS

BACKGROUND

The presence of curvature poses a fundamental limitation on the performance of a railway system. Electrification, signalling, grade crossing elimination and sophisticated equipment cannot defeat the limitations imposed by curvature (except for the slight advantage provided by tilt-body trains). This general condition is exacerbated in the Northeast Corridor northend (NYC to Boston) by the presence of more curves--and sharper curves--than in the southend (NYC to Washington). This is an artifact of the standards adopted by the predecessor railroads to the present Shoreline route.

CURVATURE STUDY

The investigation carried out in the VNTSC study centered around an examination of each of the approximately 238 curves between Penn Station and South Station.

Along with the curves, other speed restrictions present in the existing route were identified and examined, as discussed below. No detailed field examinations were possible in this study. Rather, each curve or restriction was examined through each of the following sources:

- railroad track charts
- railroad curvature listings
- railroad track geometry car measurements
- USGS topographic mapping
- railroad valuation maps
- observations from video recordings of right-of-way, indexed by milepost, provided by Amtrak.

The first finding of the investigation was that track superelevation has been systematically reduced throughout the study zone, on both Amtrak and MNCR territory. As a result of this early finding, the first approach taken was to determine the reduction of trip time if full superelevation were restored.

BASIC METHODOLOGY

A theoretical track deck was developed for the Train Performance Calculator (TPC), consisting of maximum speed limits or maximum authorized speeds for each section of route, for the existing NYC to Boston alignment. A number of assumptions underlaid this development:

1. Six inches of actual track superelevation (Ea) was assumed to be present at restricting curves in the route, with certain exceptions, as on the Hell Gate Bridge and in terminal and station areas. While this amount of superelevation can generally be

achieved, there will be isolated instances where it will prove more complex (and hence more costly) to achieve than is practicable. This may be the case, in particular, at certain MNCR locations where open deck bridges, curves, existing high-level station platforms and track centers interact to make the achievement of full superelevation too costly. Each of these isolated instances needs to be treated in detail, which was beyond the scope of this study. The full superelevation program appears in large measure to be achievable.

2. Achieving full superelevation requires adjustment to the transition curves (spirals) associated with the existing curves. Engineering specifications for spirals generally address two concerns: passenger comfort, which is speed dependent; and car twist, which is not speed dependent but depends on the degree of equalization provided by the rolling stock. Many of the specifications still in use today have their origins in the distant railway past, when truck equalization--or indeed the presence of trucks, as opposed to single-axles--was relatively primitive. Both Amtrak and MNCR utilize specifications which are more conservative than are the FRA safety standards. While this is appropriate, the specifications in use appear to exceed those used by British Rail and SNCF, for example; they also appear to exceed those recommended by AREA. The use of the existing specifications increases required spiral lengths beyond those used by other passenger carriers, which has the effect of limiting the amount of superelevation placed in curves.

It is beyond the scope of the present investigation to resolve the spiral standards issue, but its resolution is critical to achieving optimal superelevation of NEC curves. Adequate spiral transitions and runoffs are believed to be achievable to implement the full superelevation program in large measure. (As stated above, site specific evaluation is required and there will be exceptions to the general rule.)

3. Unbalanced elevation (Eu), or cant deficiency, represents the lateral force on a passenger caused by trains traversing curves at speeds in excess of equilibrium, or balanced, speed. (Equilibrium speed is the speed at which track superelevation exactly balances this lateral force, and Eu = 0). The historical American standard for unbalance is 3" Eu, which value stemmed from a series of AREA tests in 1954 on post-war passenger equipment now popularly known as the Heritage Fleet. Unbalance levels affect passenger comfort but in the range in question do not affect train safety or track stability. Railway administrations in Europe operate priority passenger trains over at least 5" unbalance, and also allow track elevations in excess of 6". This total elevation (Ea + Eu) in Europe can approach 12" on conventional (nontilt) trains.

Recent tests in the NEC have shown that conventional Amfleet cars can operate at 4" to 5" unbalance with acceptable passenger comfort. Amtrak has successfully petitioned FRA for permission to operate over designated NEC curves at 5" unbalance, under conditions contained in FRA's approval of Amtrak's petition. The present analysis assumed that with advanced technology rolling stock (TGV coaches as a well-tested example) and/or potential use of track superelevations slightly exceeding 6", a total elevation of 12" can be achieved in the NEC. Tests will be required to demonstrate the feasibility of this assumption, but there is precedent for it internationally and it is central to maximizing performance improvements in the existing NEC.

CURVE REALIGNMENTS

A graphic plot of speed vs. distance for TPC runs was analyzed to determine the potential for time savings through curvature reduction. In particular, individual curves were examined in the context of their neighbors, and "clusters" of curves were isolated which would need to be realigned together in order to achieve significant time savings in a coordinated manner. Each group of curves (cluster) was considered a realignment project.

The TPC speed table or deck was modified to reflect increased radius of curvature, and revised travel times were obtained. For each curve, the amount of track shift required was calculated. Based on the data sources described above, particularly the USGS maps and the rail line videos, adjacent development, wetlands, and terrain were identified, and quantity take-offs for estimating were developed. An overall rating of A, B, C, or D was developed, based on the degree of track shift, length of project, environmental problems anticipated, degree of displacement anticipated, complexity, and impacts on adjoining development, if any. D-rated curves were dropped from further consideration; the remaining curves were estimated with final evaluation to be made in the context of the cost and time savings associated with each project. The detailed Estimate of Curve Shift, Rating and Comment Sheets, and the Project Summary (Estimate) sheet are attached in Appendix D-1.

One finding of interest is that a number of curve realignment projects require modest shifts which are within the existing rail right-of-way. Another observation is that at certain locations the land on either side of the railroad is owned by the same landholder, perhaps allowing land swaps to take place. Because the right-of-way is up to 250 feet wide in some locations, the possibility of releasing land from rail purpose in conjunction with a realignment is also possible, theoretically allowing an increase of wetlands, for example.

Of the 34 realignment projects proposed, 33 are clusters of between one and six curves, having estimated costs ranging between \$0.5 million and \$88 million per project.

One realignment project is unique consisting of 11 curves realigned on a principally new alignment over 18 miles between Westerly and Kingston, RI, estimated to cost \$262 million.

Time savings were estimated using the TPC, assuming TGV 1-6-1 equipment, and one AEM-7 locomotive with six Amfleet coaches. The individual projects save varying amounts of time, ranging from several seconds to up to $3\frac{1}{2}$ minutes for the TGV; and up to $2\frac{1}{4}$ minutes for the AEM-7. Aggregate time savings of approximately 12 minutes and 10 minutes is achieved by all 34 realignment projects, for TGV and AEM-7, respectively.

While final decisionmaking would require more detailed time savings analyses, site surveys and cost estimate refinement, examination of the realignment projects in the different corridor segments is instructive. The table on the next page, based on the TPC runs for a TGV-like train, shows the potential time savings through realignment alone by corridor segment, cost per realignment, and average cost per minute saved by corridor segment. Costs are seen to range from approximately $31 M/minute saved on the Hell Gate Line to $142 M/minute saved on the Stamford-Bridgeport segment. The average cost per minutes saved is $70 million overall, and $59 million excluding Shell-Bridgeport.

For the purposes of the development of programs for improvement in this study, the most expensive two segments on Metro-North were not included. Clearly, the requirement to move four tracks and associated catenary in the most urban area of the New Haven Line causes these costs to be highest. The curve realignments are included in Programs 4 and 5; for Program 5 the curve realignments between Old Saybrook, CT and Kenyon, RI are bypassed and would not be implemented.

GLOSSARY

Alignment - The horizontal location of a railroad as described by curves and tangents.

Amfleet Car - A type of unpowered stainless rail passenger car used by Amtrak.

Automatic Block Signaling (ABS) - A system of sequential track segments (blocks) usually about 2000-4000 feet or more long, which are electrically isolated from one another and equipped with circuitry that detects the presence of a train or the position of a switch. This information is conveyed through the system to adjacent blocks and via wayside or in-cab signals to approaching trains, informing them of the track conditions ahead.

Balance Speed - The speed a train can traverse a curve and produce no net lateral force on the track. (The superelevation, or cant, exactly compensates for the centrifugal force.)

Ballast - Selected material placed on the roadbed for the purpose of holding the track in line and surface.

Block - A length of track of defined limits, the use of which by trains and engines is governed by block signals, cab signals, or both.

Block Signal - A fixed signal at the entrance of a block to govern trains and engines entering and using that block.

Cab Signal - A signal located in engineman's compartment or cab, indicating a condition affecting the movement of a train or engine and used in conjunction with interlocking signal and in conjunction with or in lieu of block signals.

Cant - In curves, the vertical distance, in inches, that the outer rail is above the inner rail (also, Superelevation).

Cant Deficiency - The required additional cant, in inches, which would be required to produce balance-speed conditions; it varies with speed.

Catenary - A system of wires, suspended from poles or towers, consisting of a "contact wire" through which electricity is fed to trains by means of a pantograph, a "messenger" wire, which supports the contact wire at a relatively constant height from top of rail, and "stringers" which connect the messenger and contact wire.

Centralized Traffic Control (CTC) - Used in conjunction with Automatic Block Signaling, CTC systems record and monitor track conditions continuously at a central location and provide this information via teletype, cathode ray tube, and other means to train dispatchers. Normally there is also a display board with lights and lines in a schematic representation of the railroad being controlled, which provides a visual representation of the entire system, including track occupancy, train location, switch position and other pertinent information. Dispatchers can remotely establish train routing and reset switches and convey this information via the signal system to train operators.

Crossover - Two turnouts with the track between the switch frogs arranged to form a continuous passage between two nearby and generally parallel tracks.

Curve - Compound - A continuous change in direction of alignment by means of two or more contiguous simple curves of different degrees having a common tangent at their junction points.

Curve - Degree of - The angle subtended at the center of a simple curve by a 100-ft chord.

Curve - Spiral - A curve whose degree varies either uniformly or in some definitely determined manner so as to give a gradual transition between a tangent and a simple curve, which it connects, or between two simple curves.

Curve - Reverse - Two contiguous simple curves in opposite directions, with a common tangent at their junction point.

Curve - Vertical - An easement curve in the track to connect intersecting grade lines.

Grade Crossing - A highway crossing at grade.

Headway - Distance of time between trains.

Interlocking - An arrangement of signals and signal appliances so interconnected that their movements must succeed each other in proper sequence and for which interlocking rules are in effect. It may be operated manually or automatically.

Line - The condition of the track in regard to uniformity in direction over short distances on tangents, or uniformity in variation over short distances on curves.

Lining Track - Shifting the track laterally to conform to the established alignment.

Metroliner - An electric multiple-unit car designed and built by the Budd Co. for demonstration on the Northeast Corridor by the Penn Central Railroad in the late 1960s. The term is also used to describe a premium service offered by Amtrak in the Corridor, originally using these Budd-built cars, but more recently using AEM-7 hauled Amfleet cars.

Out of Face (Referring to Track Work) - Work that proceeds completely and continuously over a given piece of track as distinguished from work at disconnected points only.

Pantograph - A device mounted on the roof of a powered rail vehicle to collect electricity from a catenary.

Profile - A line representing the ground surface or an established grade line, or both, in relation to the horizontal.

Signal Aspect - A signal convention, established by railroad operating rules, that conveys information on track condition to train operators.

Surface (Track) - The condition of the track as to vertical evenness or smoothness.

Superelevation - In curves, the vertical distance, in inches, that the outer rail is above the inner rail (also, Cant); used to counteract the centrifugal force of a train in a curve.

Switch frog - The fixed portion in the center of a track switch.

Tilt-body Vehicle - A rail passenger vehicle designed so that the passenger compartment will rotate a few degrees in curves, counteracting centrifugal force and consequently reducing the acceleration felt by passengers riding in the vehicle in curves.

Turnout - An arrangement of a switch and a frog with closure rails, by means of which rolling stock may be diverted from one track to another.

Yard - A system of tracks within defined limits provided for making up trains, storing cars, and other purposes, over which movements not authorized by timetable or by train-order may be made, subject to prescribed signals and rules, or special instruction.

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