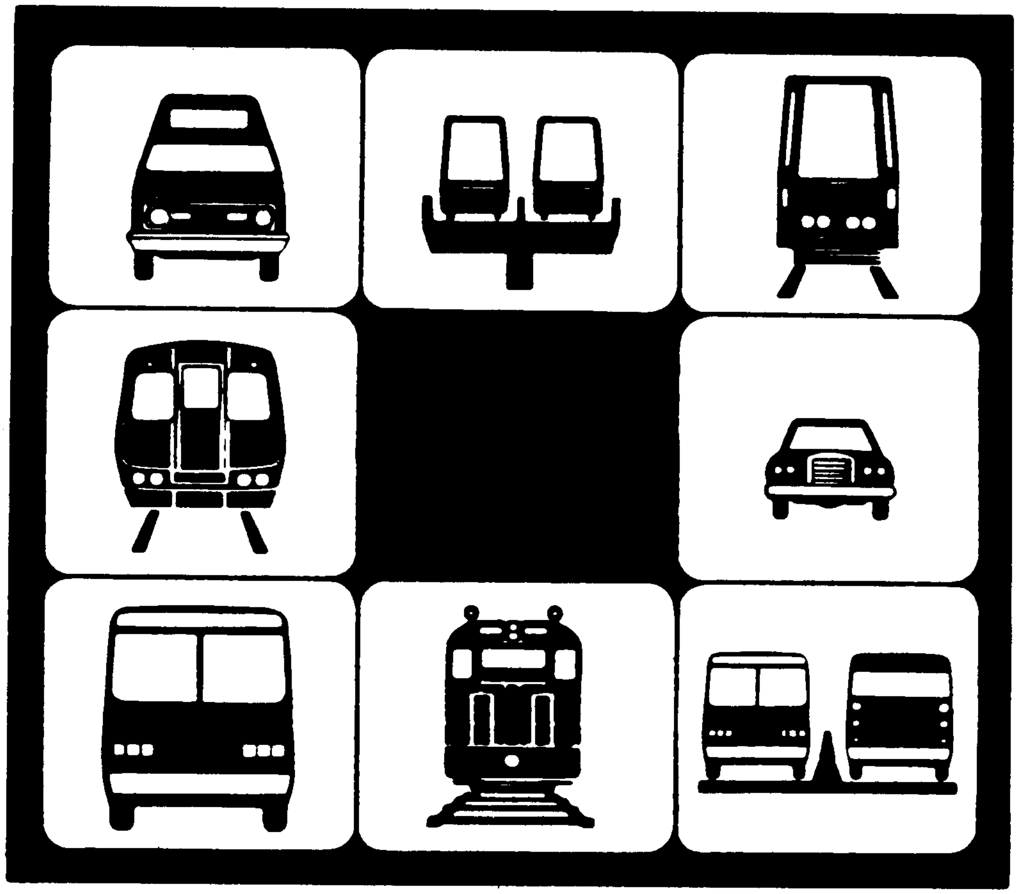
U.S. Department
of Transportation

Rail Modernization Study

April 1987



FEDERAL TRANSIT ADMINISTRATION

Rail Modernization Study

Final Report
April 1987

Prepared by

Gannett Fleming Transportation
Engineers, Inc.

In association with

Lea, Elliott, McGeay & Company
Batelle Columbus Laboratories
Madison Madison International
Ammann & Whitney
UTD Incorporated
LTI Consultants, Inc.

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PREFACE

This study summarizes the results of a multi-year assessment of the rail transit and commuter rail systems. The work was based on an earlier study design effort. The purposes of the study were to determine the costs of upgrading and modernizing urban rail transit facilities and to provide an initial cost/benefit assessment of the proposed improvements and associated capital costs. The study deals with 34 rapid, light and commuter rail systems.

The study responds to a request made of the U.S. Department of Transportation by the Senate Appropriations Committee. It was undertaken by the Office of Grants Management of the Urban Mass Transportation Administration (UMTA). The study was directed for UMTA by Kristen D. Clarke, who served as the Contracting Officer's Technical Representative.

The study was performed by Gannett Fleming Transportation Engineers, Inc. (GFTE) in association with:

Lea, Elliott, McGean & Company
Battelle Columbus Laboratories
Madison Madison International
Ammann & Whitney
UTD Incorporated
LTI Consultants, Inc.

The primary personnel from these organizations who contributed to this endeavor are listed in Table A.

Timely technical review and guidance has been provided by a Rail Modernization Study Liaison Board, consisting of experienced transit operators and managers and representatives of the American Public Transit Association (APTA). Members of this Board are listed in Table B.

The Project Manager for the study wishes to acknowledge direction and support given throughout the study by Kristen D. Clarke and Brian J. Cudahy, of UMTA's Office of Grants Management, Richard Steinmann of UMTA's Office of Budget and Policy, and Brian Sterman of UMTA's Region II Office in New York. The cooperation of all the transit authorities in providing data and in arranging on-site inspections is also gratefully acknowledged.

TABLE A

RAIL MODERNIZATION STUDY PERSONNEL

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TABLE B

RAIL MODERNIZATION STUDY LIAISON BOARD*

Transit System	Representative
Chicago Transit Authority	Bernard J. Ford, Executive Director
New York City Transit Authority	Eugene Callaghan, Director of Rapid Transit Capital Programs
The State of New York Metropolitan Transportation Authority	H. Lee Hennig, Director, Capital Program Administration/ William Goldstein, Director Capital Program Budgets
Port Authority Trans-Hudson Corporation	James J. Kirk, Deputy Director
Illinois Department of Transportation	Stephen Schindel, Bureau Chief, Northeastern Illinois Programs
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Massachusetts Bay Transportation Authority	John I. Williams, Project Manager - Design
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Staff, American Public Transit Association	
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	Donald Dzinski, Manager - Safety and Program Development

*Titles and Affiliations as of December 1984

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

1.0 SUMMARY

1.1 SYNOPSIS

This chapter summarizes the results of a study requested by Congress, and conducted for the Urban Mass Transportation Administration (UMTA), to assess the costs for a 10-year period of rehabilitating and modernizing existing rail systems to a level consistent with current standards of safety, reliability and aesthetics for new rail systems. First, these improvement actions and costs were developed using a rigorous engineering approach. Second, initial benefit/cost analysis methods were applied to reflect the cost effectiveness of the possible improvement actions on each of the established rail segments/branches.
Although the benefits of rail modernization may be difficult to estimate, several reasonable proxy measures were developed in this study to provide some initial insight into the benefits associated with the capital improvements.

This summary describes the results of the multi-year investigation of the 34 transit systems and provides a context for understanding the findings. Included are:

- A summary of the study results.
- A brief description of the history of the Rail Modernization funding program and the background out of which the study emerged.
- A description of the study design including the purposes, objectives and scope.
- A description of the analysis which was undertaken including the general procedures followed.

The remainder of the report provides more detail on the study methodology and results. The report includes the following chapters:

- Chapter 2 - Introduction - This chapter describes the background out of which this study developed, definitions used during the course of the study and general procedural concepts.
- Chapter 3 - Current Condition -This chapter reports on the actual physical condition, as of 1983, of all of the rail systems. These various systems are broken down into seven system elements (e.g., track, vehicles, power distribution, stations, etc.). Data are presented on the useful life of the elements, as well as their anticipated rate of deterioration in the future.
- Chapter 4 - Proposed Repair and Replacement Actions - This chapter describes the actions needed to restore all system elements of all of the rail systems to good condition.
- Chapter 5 - Capital Cost Estimates and Benefits - This chapter provides estimates of the cost, in 1983 dollars, of making the improvements identified in Chapter 4. It also includes conclusions on the investment worthiness of the proposed actions.
- Chapter 6 - Sources of Local Financing for Rail Modernization - This chapter discusses historical funding patterns in the urbanized areas where rail systems operate, and introduces several innovative funding techniques that bear promise for meeting a portion of the future investment costs in these areas.

The Appendix to this report describes one of the benefit/cost estimation procedures used in this study; this method was developed by London Transport International (LTI).

1.1.1 CURRENT CONDITIONS

One of the major products of the Rail Modernization Study is an assessment of the current condition of rail transit systems on the basis of systematic, on-site inspections using consistent definitions and consistent assessment procedures. This information is summarized in Table 1.1, and shows the condition of each engineering element and subelement in terms of the condition definitions provided in Table 2.1.

The table indicates that, in general, maintenance facilities and yards are in the worst condition, with 58 percent in "bad" or "poor" condition. Self-propelled rail cars (i.e., rapid transit and light rail cars and both electric and diesel-powered commuter rail cars) are also a problem with 47 percent in "bad" or "poor" condition. On the other hand, 66 percent of the electrical substations, 55 percent of unpowered (i.e., locomotive-hauled) rail cars, 49 percent of locomotives and 46 percent of tunnels are in "good" or "excellent" condition, and thus will require only limited actions to ensure that they will remain in at least good condition by the end of the 10-year period for the study. Section 1.8 and Chapter 3 provide detailed assessments of the current condition of each of these elements for each system in the study.

TABLE 1.1

Rail System Current Conditions
by Engineering Subelement

(Percent of Element in Each Condition)

Element	CONDITION				
	Bad	Poor	Fair	Good	Excellent
Track	0	7	49	31	12
Vehicles					
Self-Propelled Rail Cars	23	24	18	28	7
Locomotives	3	13	35	49	0
Unpowered Cars	3	10	32	43	12
Power Systems					
Substations	6	23	5	43	23
Overhead	20	12	27	36	5
Third Rail	13	26	19	36	6
Stations	0	15	56	23	6
Structures					
Bridges	1	16	51	28	4
Elevated	0	1	80	3	16
Tunnels	0	5	49	35	11
Maintenance					
Facilities	4	54	14	24	4
Yards	4	53	26	16	1

1.1.2 IMPROVEMENT ACTIONS

The improvement actions to restore all the rail system subelements to a "good" condition are provided in Table 1.2. The various levels of improvement include "modernization", "rehabilitation" or "refurbishment", and these terms are defined in Section 1.9. For significant quantities of certain subelements already in "good" condition (track, substations, third rail and overhead, for instance), no improvements may be necessary as they should remain in "good" condition for the 10-year period without any capital improvement. Note, however, that these elements will still require regular continuing maintenance to maintain this "good" condition. For a number of vehicles, on the other hand, more than one capital improvement may be needed during the 10-year period to ensure they reach the end of the period in "good" condition. This is because of the relatively short useful life of many vehicle components.

TABLE 1.2

Improvement Actions by Engineering Subelement

Element	Total Quantity	Quantity for Improvement	Percent of Quantity for Improvement		
			Modern.	Rehab.	Refurb.
Track	5,102 mi.	2,805 mi.	44	31	25
Vehicles					
Self-Propelled Rail Cars	12,963	14,118*	18	51	31
Locomotives	416	395*	28	65	7
Unpowered Cars	1,671	1,633*	18	8	74
Power Systems					
Substations	673	193	65	4	31
Overhead	1,351 mi.	761 mi.	66	0	34
Third Rail	1,895 mi.	758 mi.	82	14	4
System-Wide Controls	29	28	54	25	21
Stations	27.7 msqf	24.5 msqf	15	41	44
Structures					
Bridges	11.4 msqf	10.7 msqf	1	67	32
Elevated	1.2 mlft	1.0 mlft	1	97	3
Tunnels	1.6 mlft	1.5 mlft	1	59	40
Maintenance					
Facilities	8.6 msqf	6.8 msft	63	10	27
Yards	62.9 msqf	52.4 msqf	66	13	21

*Certain vehicles require more than one improvement action during the 10-year cost estimation period to remain in "good" condition at the end of the 10-year period.

ABBREVIATIONS: mi - miles
msqf - million square feet
mlft - million linear feet

The type of improvement action varies widely between system element and subelement. For example, many of the stations (44 percent) would require only refurbishment to be in "good" or better condition by the end of the 10-year period. On the other hand, the power system facilities were typically well over 50 years old. Hence they were of obsolete design and contained obsolete components, making repair or partial replacement infeasible. In these cases, full replacement with all new components ("modernization") would be required for these elements to be in "good" or better condition at the end of the 10-year period. A number of system-wide control systems were also of obsolete design and thus would require replacement ("modernization") rather than "rehabilitation" or "refurbishment". Section 1.9 and Chapter 4 provide more detail on the proposed actions.

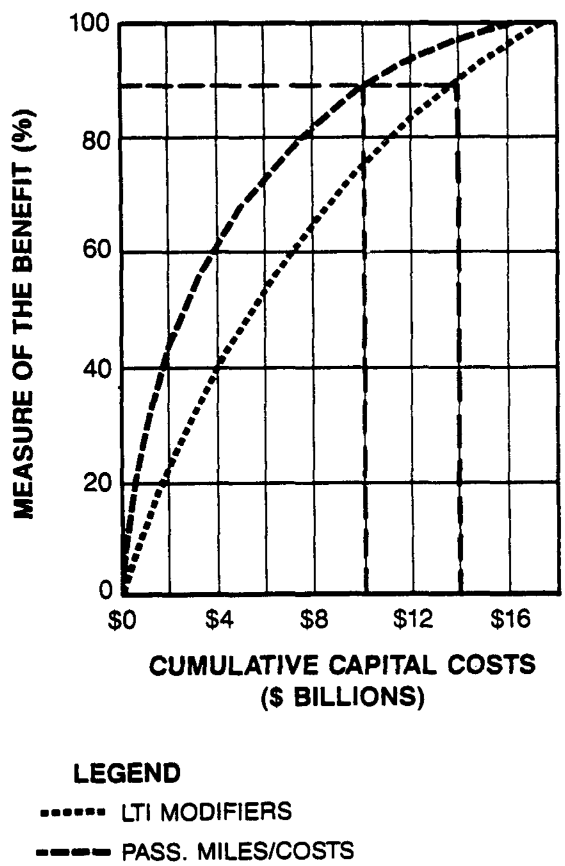
1.1.3 Estimates of Costs of Varying Benefit Levels

Two methods of assessing the cost effectiveness of these improvements were applied. These methods provide one means of identifying the most worthy rail segment improvements which might be accomplished first. Results of this analysis of expected benefits for various capital expenditure levels were achieved by listing the 186 segments/branches in accordance with the benefit/cost ratio of each, with the highest ratios first and the lowest ratios last.

- Relationship of Benefits to Costs

  The relationship between national benefits and costs is shown in Figure 1.1. Two measures of benefits were used: the Passenger Miles (PM) and LTI methods. The LTI method used unit benefit modifiers to estimate operating cost savings and passenger benefits that are attributable to the proposed capital improvements. A benefit cost ratio for each improvement was developed by adding the operating cost savings and passenger benefits and dividing by the cost. To make these measures comparable, the benefits for each segment/branch were converted to a percentage of the national total. The values for each segment/branch were listed in a descending order in accordance with their benefit/cost ratio. Thus, the cumulative measures of benefits for each segment/branch, in percentages, are shown in relation to the cumulative capital cost of improvements (in $-billion) for each segment/branch. An investment of $17.876 billion would achieve 100 percent of the expected benefits for all 186 segments/branches, while about half that would achieve between 69 and 84 percent of the benefits, depending on the method used.

FIGURE 1.1
TOTAL BENEFITS VS. TOTAL CAPITAL COSTS FOR FULL REHABILITATION (ALL SYSTEMS)



Some of the significant results of this analysis are summarized in the following table:

TABLE 1.3

Range of Benefits for Alternative Funding Levels

(1983 Dollars)

Levels of Funding		Percentage of Benefits	
Percent	Funding ($-Billion)	LTI	PM
50%	$ 8.8	69%	84%
60%	$10.7	77%	90%
75%	$13.3	88%	96%

These data suggest that a capital investment of 50 percent of the total estimate for improvements ($8.8 billion) could achieve from 69 to 84 percent of the expected benefits. A 75 percent investment ($13.3 billion) could result in 88 to 96 percent of the expected benefits.

Conversely, the information in Figure 1.1 suggests that 90 percent of the expected benefits could be realized by funding approximately 60 percent ($10.7 billion) of the total improvement costs (PM method) or 78 percent ($13.9 billion) of the total improvement costs (LTI method).

With a funding level of $8.8 billion, between $6.5 and $6.9 billion would be for rail rapid transit system improvements (74 to 78 percent) and between $1.7 and $2.0 billion (20 to 23 percent) for commuter rail, about half of which is for the New York urbanized area, and between $0.2 and $0.4 billion (2 to 3 percent) for light rail. This is in contrast to the total costs (i.e., $17.8 billion) where 59 percent is for rapid rail, 34 percent is for commuter rail and 6 percent is for light rail. The heavier utilization per mile of rapid rail make these improvements more cost effective than those on commuter rail and much more cost effective than those on light rail systems. Many very low-utilization commuter rail segments come out especially poor by this measure. Improvements on the relatively new transit systems in Washington, Atlanta, San Francisco (BART and MUNI), San Diego and the Lindenwold Line in Philadelphia tend to come out especially well by this measure because their good current condition requires only limited expenditures of capital funds to ensure continued good conditions, as well as the fact that these systems have relatively high levels of ridership per mile and appear to be performing good routine maintenance.

These results highlight the need for cost-effectiveness analyses in prioritization of rail modernization improvements. The cost of possible improvements, including those which ensure elimination of potentially unsafe conditions, must be weighed against the benefits of the improvements, including retaining service compared with alternative ways of meeting transit demands given the utilization of the line. Segments should be analyzed to determine whether utilization warrants continued operation, whether capital improvements are cost effective, or whether alternative modes of transit could more effectively satisfy the transportation requirements.

1.2 THE CONTEXT FOR THE RAIL MODERNIZATION STUDY

A full understanding of the results of this study as presented above requires an awareness of the context out of which this study emerged. This section describes briefly the funding program for Rail Modernization as well as the background for the Congressional request for the study.

1.2.1 THE UMTA RAIL MODERNIZATION FUNDING PROGRAM

Federal support for Rail Modernization dates from the very beginnings of the federal mass transit program in 1964. Indeed, part of the rationale for the federal program itself was a growing realization that a large backlog of deferred maintenance on the rail systems had developed. This deterioration of condition was causing inefficient and unreliable rail transit service. It was believed that a new infusion of public funds was required for it to be reversed. Dealing with the backlog quickly became the main focus of the Rail Modernization activity.

Initially, Rail Modernization activities were not distinguished from other eligible activities in the Section 3 discretionary capital program. However, with the growth in funding levels and addition of the Section 5 formula program, directed primarily at routine bus activities, in FY-'77 the Section 3 resources were categorized to distinguish between Rail Modernization, New Starts (i.e., construction of all new fixed guideway systems or major extensions to old systems) and bus activities. The establishment of the categories was also brought on by a need to distinguish between funds for modernization of existing assets and those for system expansion.

1.2.2 DEVELOPMENT OF THE CONGRESSIONAL REQUEST FOR A RAIL MODERNIZATION STUDY

The establishment of a specific category of funds for Rail Modernization led to an increasing desire to be able to set the level of funds provided based on better estimates of the condition of the rail systems and the cost of their restoration. By 1979, a number of estimates had been made of the "need" for Rail Modernization funding. These estimates were typically made by transit industry groups usually as a result of surveys by the rail transit operators. They suffered from a number of shortcomings typical in "needs" estimates made for a variety of public works programs.

- o There were inconsistencies in the definitions of what should be included. Some areas were including extensions of existing systems while others were more conservative in focusing only at existing systems.

- o The survey techniques themselves were often flawed. By not providing for uniform definitions, and by relying only on available information, inconsistencies were built in.

- o No consistent basis for estimating the current conditions of the rail systems was available. Each area had different definitions of conditions and performance and different standards for this performance.

- o No consistent methods were in place for estimating costs. Areas did not use consistent methods for assessing the improvements necessary to produce improved conditions, nor were there consistent methods for assessing the costs of these improvements.

- o No data was available on the benefits of the prospective investments that would allow for judging their economic merits.

As a result of Congressional dissatisfaction with these estimates, and a desire for credible, consistent estimates of the cost to improve these systems and eliminate the backlog of deferred maintenance, in the Senate Report, the report accompanying the Fiscal Year 1980 Department of Transportation and Related Agencies Appropriation Act, the Congress directed submittal of

> "...an estimate of the actual costs...of replacing overage rail rolling stock; [and] of rehabilitating and modernizing existing rail systems to a level consistent with current standards of safety, reliability, and esthetics for new rail systems;..." pg. 41

The Congressional request called for the estimate to be made covering a 10-year period. This study responds to that request.

1.3 THE RAIL MODERNIZATION STUDY PROCESS

1.3.1 STUDY DESIGN PHASE

The Rail Modernization Study was conducted in three phases. The initial phase was devoted to development of a detailed Study Design. This phase was begun in mid-1981 and was concluded with a detailed report completed in June 1982. The Study Design laid out an approach to be taken to determine the current condition of the rail systems, the improvements which would be required and the costs of these improvements. It also described the goals of safety, reliability, operating efficiency and aesthetics posed in the Congressional request for the study which would serve as criteria for the selection of improvement projects. The Study Design laid out three alternative scenarios for the technical analysis based on cost and level of work.

1.3.2 ENGINEERING COST ESTIMATE PHASE

The Engineering Cost Estimate Phase of the study was the most intensive. As described below, this phase involved the physical assessment of the condition of the rail systems, including site inspections conducted between late 1983 and mid-1984, an assessment of the improvements which would bring the condition of each system element to at least a "good" condition and an estimate of the cost of these improvements. This work was completed in mid-1985.

1.3.3 COST-EFFECTIVENESS PHASE

Early in the study process it became clear that the results of the Engineering Cost Estimate Phase alone would not be sufficient to provide a complete picture of the strategies required to achieve cost-effective investments in the improvement opportunities identified during that phase. Improvements selected to solve particular engineering problems encountered during inspections of the systems did not, in themselves, include estimates of the benefits to be achieved by making those improvements. In addition, not all of the improvements proposed to fully rehabilitate the rail systems may be desirable. Most of the systems were developed prior to World War II and travel patterns and systems utilization have sometimes changed substantially. Therefore, it was important to determine the cost-effectiveness of the proposed improvements as one possible means of evaluating and staging the improvements. Accordingly, the Cost-Effectiveness Phase was designed and implemented. This phase began with completion of the Engineering Cost Estimate Phase and was completed in mid-1986. This phase included development and application of cost/benefit methodologies to assess the relative investment worthiness of rail system improvements identified in the prior phase.

1.4 STUDY GOALS AND OBJECTIVES

The UMTA Rail Modernization Study has as its primary goal to determine the costs of upgrading and modernizing the urban rail transit facilities, while providing an initial cost/benefit assessment of the proposed improvements and associated capital costs.

The technical approach developed to satisfy this goal involved accomplishment of the following tasks:

1. Establish current conditions of the rail transit systems.
2. Identify repair and replacement actions necessary to restore all rail system elements and subelements to at least a "good" condition.
3. Determine costs of improvements.
4. Develop methods for an initial estimate of the relative costs and benefits of the rail transit improvement actions.

5. Estimate the benefits and costs of proposed improvements to the different transit system segments.
6. Develop a priority order for system segment improvements and estimate of the benefits to be derived from varying levels of capital expenditure.

An important first step was the early establishment of the basic goals of rail modernization itself. The following goals were developed, with the assistance of the Rail Modernization Study Liaison Board (RMSLB), to provide insight on how best to estimate the requirements for rail transit system improvements:

- Sustain or improve existing levels of safety; including the safety of passengers, operating/ non-operating personnel and equipment.

- Sustain or improve operational reliability and availability; including all aspects of schedule adherence, system availability and maintainability.

- Sustain or increase operating efficiency in terms of costs and service levels; including the upgrading of system elements to reduce operating and maintenance costs and improve service levels.

- Sustain or improve existing levels of security; including improvements that are necessary to protect passengers and operating personnel from assaults and equipment and property from vandalism.

- Sustain or improve system aesthetics in terms of comfort and noise pollution; including improvements that are necessary to make public transit more attractive to the passengers.

Another major step was to obtain agreement on the major system elements which the study would examine. These system elements and their definitions, provided the necessary guidance on "what" would be inspected and evaluated at each transit system. The major system elements that were selected are:

- Track
- Vehicles
- Power Distribution
- System-wide Controls
- Stations
- Structures and Facilities
- Maintenance Facilities

Each of the major system elements was further divided into subelements/ subsystems to assess further the existing physical condition and define necessary improvements.

This study includes an evaluation of 34 rail transit systems; 11 rapid rail, 8 light rail, and 15 commuter rail systems in 13 urbanized areas throughout the United States. The rail transit systems consist of approximately 5,100 miles of track, 15,000 vehicles, 675 power substations, 1,350 miles of overhead wire, 1,895 miles of third rail, 29 system-wide control systems, 2,225 stations and station stops, 3,800 structures and bridges, 140 tunnels, and 150 maintenance facility buildings.

The primary study objectives are thus as follows:

- Fulfill the Congressional request by developing actual costs of upgrading and modernizing the existing rail systems to a level of "good condition" consistent with current requirements of safety, reliability, efficiency and aesthetics.

- Complete an inventory of each rapid, light and commuter rail system including all system elements, track, vehicles, stations, power distribution, signal and communication systems, structures and maintenance facilities.

- Establish and apply a systematic, detailed approach to assessing the current condition, developing improvement and repair actions and preparing cost estimates for each rail transit system which transit authorities could use themselves in the future.

- o Establish applicable system segments on each transit system, obtaining estimates of the rail passenger utilization on each segment, and then estimating the capital costs and benefits of proposed improvements to those segments.

- o Develop a methodology to assist in the prioritization of proposed improvements to each of the established transit system segments.

- o Provide an assessment of the cost-effectiveness of the proposed improvements.

- o Provide an initial assessment of the cost-effectiveness of the proposed improvements.

- o Conduct an assessment of the ability of the local areas to undertake major capital investments.

1.5 STUDY SCOPE

To further define the tasks necessary, a number of bounding criteria were established to better identify the scope of the work to be completed. These criteria were designed to focus the study exclusively on Rail Modernization rather than on the much broader possible range of actions which could be taken to improve the rail systems studied. Thus, a distinction is made between improvements to rail transit systems, subsystems or components brought about by capital investment, and improvements caused by such management actions as operating procedures, maintenance practices, service levels or personnel actions.

The scope of this study is limited to improvements which can be derived from capital investment. It is important to note, however, that capital improvements developed during this study are not necessarily eligible as capital expenses under current provisions of the federal urban mass transportation grant program, nor is there a presumption that such eligible costs would necessarily be covered with federal funds.

This study also focuses on upgrading and modernizing existing rail transit vehicles and structures and facilities. It is not the scope of this study to evaluate and make recommendations beyond the status quo. The study does not, in other words, include rail car fleet expansion based on future ridership projections; relocation of maintenance facilities for operational reasons; closing or combining stations due to patronage changes; or, on the other hand, abandoning outright under-utilized rail lines. The extension of electrification on commuter lines which currently operate both electric and diesel-powered trains, as well as the deployment of electrification on routes where it does not now exist, are also beyond the scope of the study. In a few instances, however, where projects to upgrade a commuter rail line are already underway and include the extension of electrification, such work has been incorporated in the study.

As explained in this report, the physical assessments of the system elements and subsystems were necessarily done on a sample basis; it was neither feasible nor essential to conduct a survey which examined 100 percent of all equipment and facilities. The nature and extent of the sampling varied from transit system to transit system and from system element to system element since they varied greatly in size, age, and condition. It was necessary to select a general statistical sampling technique that could be employed, as appropriate, for each transit system inspection. Samples were stratified into groups by type and age to ensure a representative sampling of the system. For example, cars indicative of each fleet in a system were inspected. Stations were selected to give a cross-section of historic, subway, at-grade and elevated stations found on each transit system. Similarly, various types of bridges and structures were selected to ensure that the samples inspected were representative of all of the bridges in a system. The actual size of the statistical sample varied for each stratified group and for each system element and transit system because a sufficient amount of data had to be collected to provide "confidence" in the total projections (i.e., the results of the inspection of 15 to 20 percent of the track were used to project the condition of 100 percent of the track). As a result of this sampling process, the condition, improvement requirements and costs could be estimated for 100 percent of each system element and transit system.

The results of the engineering evaluation were combined with two methodologies for assessing the benefits in the cost-effectiveness phase. The first method simply assessed the number of passenger miles served by the proposed improvements. The second, developed by LTI, attempts to assess the net social benefits of the improvements in terms of travel time reductions, as well as operating cost savings. These methodologies include major assumptions on operating and maintenance cost savings in addition to passenger-related benefits. Cost savings are a function of the element improved and passenger benefits are a function of the improvement and the passenger mileage affected. In view of the fact that relationships between benefits and levels of improvement have not yet been established for U.S. transit systems, LTI was requested to apply their experience in the evaluation of rail transit projects in London in estimating benefits of proposed improvements to the different elements on U.S. systems. The methodology is explained in more detail in the Appendix to this report.

1.6 RAIL SYSTEMS EVALUATED

A list of rail systems evaluated during this Rail Modernization Study is provided in Table 1.4. This list includes most of the major rapid rail, light rail, and commuter rail systems in the United States. Other rail modes of transit service such as cable cars, personal rapid transit systems, monorails, inclined railways, certain largely tourist-oriented trolley systems, and some small commuter rail systems were not included. Intercity rail passenger services, under Section 403(b) of the Rail Passenger Service Act, were omitted.

1.7 GENERAL PROCEDURES FOR DEFINING PROJECTS

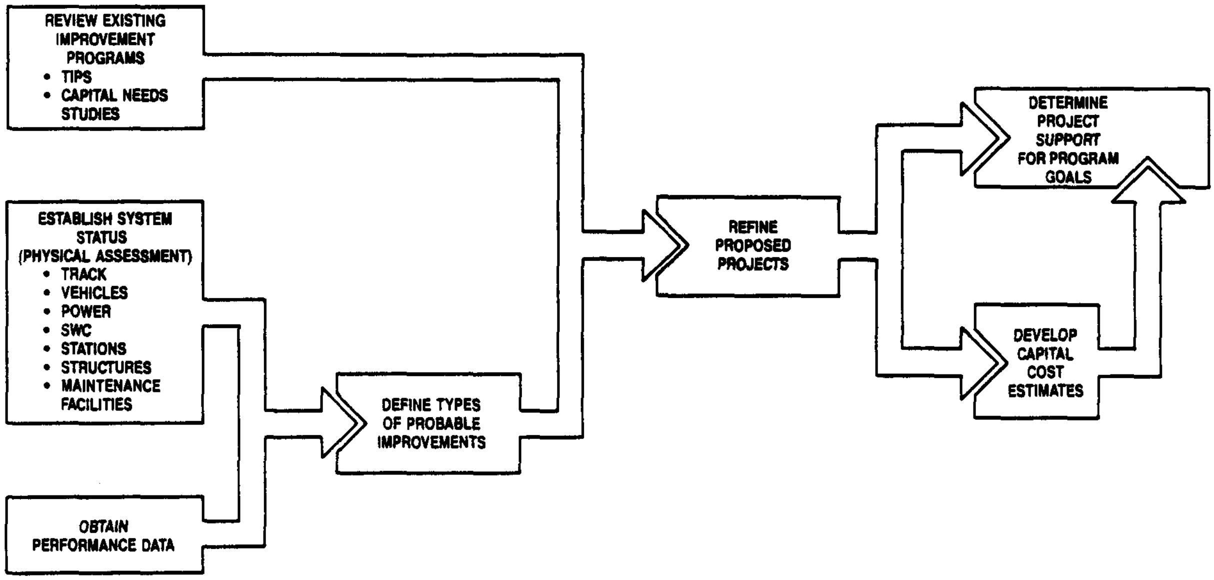
The study addresses various improvement projects for upgrading and rehabilitating the several elements of a rail transit system. The general procedure for defining such projects is illustrated in Figure 1.2. First, existing local improvement programs and plans, such as the Transportation Improvement Program (TIP), were reviewed. Second, a physical assessment was conducted of each rail transit system to establish conditions of track, vehicles, power distribution, system-wide controls, stations, structures, and maintenance facility system elements. Third, performance data were collected to obtain as much insight as possible into problems that might require some type of improvement to enhance performance. Throughout the conduct of this study, it was found that such performance data as time-between-failures were essential to identify improvements that should be made to the various transit system elements that were not obtainable merely from the physical assessment. For example, equipment that was in good physical condition may not have been operating properly. After different types of probable improvements were defined by the Consultant Team, they were compared with the improvement programs that were included in the transit improvement programs and capital planning studies in order to determine which improvement programs and projects had already been funded. Care was taken to exclude projects that had already been funded,

TABLE 1.4

RAIL SYSTEMS EVALUATED IN RAIL MODERNIZATION STUDY

Major Rail Area	Type of Transit System	Transit Operating Authority
Boston	Rapid Rail Light Rail Commuter Rail	Massachusetts Bay Transportation Authority (MBTA) Massachusetts Bay Transportation Authority (MBTA) Massachusetts Bay Transportation Authority (MBTA)
New York	Rapid Rail Rapid Rail Commuter Rail Commuter Rail	New York City Transit Authority (NYCTA) Staten Island Rapid Transit Operating Authority (SIRTOA) The Long Island Rail Road Company (LIRR) Metro-North Commuter Railroad Company (Metro-North)
New York/ Northern NJ	Rapid Rail Light Rail Commuter Rail	Port Authority Trans-Hudson Corporation (PATH) New Jersey Transit Corporation (NJTC) New Jersey Transit Corporation (NJTC)
Southern NJ/ Philadelphia	Rapid Rail	Port Authority Transit Corporation (PATCO)
Philadelphia	Rapid Rail Light Rail Commuter Rail	Southeastern Pennsylvania Transportation Authority (SEPTA) Southeastern Pennsylvania Transportation Authority (SEPTA) Southeastern Pennsylvania Transportation Authority (SEPTA)
Pittsburgh	Light Rail Commuter Rail	Port Authority of Allegheny County (PAAC) Port Authority of Allegheny County (PAAC)
Washington, D.C.	Rapid Rail Commuter Rail	Washington Metropolitan Area Transit Authority (WMATA) Maryland Department of Transportation/Maryland Rail Commuter Service (MARC)
Chicago	Rapid Rail Commuter Rail	Chicago Transit Authority (CTA) Regional Transportation Authority (RTA) o Burlington Northern, Inc. (BN) o Chicago and North Western Transportation Co. (C&NW) o Illinois Central Gulf Railroad Co. (ICG) o Northeast Illinois Railroad Corporation (NIRC)/Rock Island District (RI) o Northeast Illinois Railroad Corporation (NIRC)/Milwaukee Road District (MR) o Norfolk & Western Railway Co. o Northern Indiana Commuter Transportation District (NICTD)/Chicago South Shore & South Bend Railroad (CSS&SB)
Cleveland	Rapid Rail Light Rail	Greater Cleveland Regional Transit Authority (GCRTA) Greater Cleveland Regional Transit Authority (GCRTA)
Atlanta	Rapid Rail	Metropolitan Atlanta Rapid Transit Authority (MARTA)
New Orleans	Light Rail	Regional Transit Authority (RTA)
San Francisco	Rapid Rail Light Rail Commuter Rail	San Francisco Bay Area Rapid Transit District (BART) San Francisco Municipal Railway (MUNI) California Department of Transportation (CALTRANS) - San Francisco
San Diego	Light Rail	San Diego Metropolitan Transit Development Board (MTDB)

FIGURE 1.2
DEFINITION AND ESTIMATION OF RAIL MODERNIZATION PROJECTS



whatever the source of funds. This comparison resulted in a refinement of the proposed projects that could be considered for funding during the 10-year period. After proposed projects were identified and defined, capital cost estimates were developed and a determination was made of the impact that each project might have on each of the different program goals (safety, operational reliability, operating efficiency, security, and system aesthetics).

Definitive requirements for assessing the condition of each rail system were developed to ensure ultimate credibility of the results and that the resultant evaluations would be consistent and supportable. Standardized procedures were developed for the physical inspection of each of the transit systems, and orientation meetings/training sessions were conducted to train the technical assessment team personnel. Pre-inspection data forms were designed and this information was collected before the physical inspections to minimize the requirements for lengthy inspections by the technical specialists.

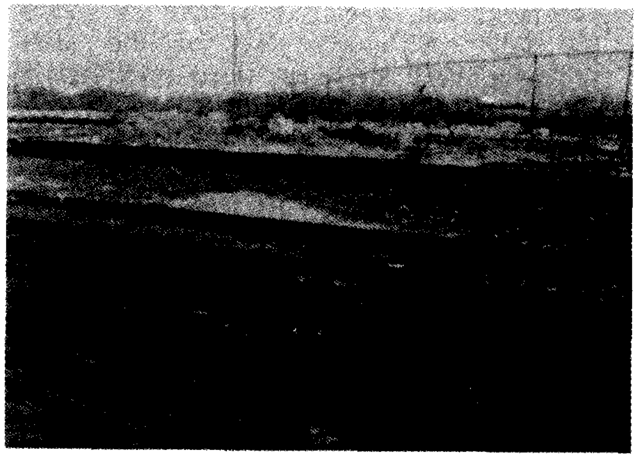
1.8 SUMMARY OF CURRENT CONDITIONS

The transit systems were inspected during the period from November 1983 to May 1984. Each system element was evaluated to determine its present condition and establish the improvement requirements and associated capital costs. Specific definitions for five condition categories of "excellent", "good", "fair", "poor" and "bad" condition were developed prior to the conduct of the actual physical inspections. These are defined as follows:

- o Bad - In a condition where continued use presents potential problems.
- o Poor - Requiring frequent major repairs (i.e., less than 6 months).
- o Fair - Requiring frequent minor repairs (less than 6 months) or infrequent major repairs (more than 6 months).

- o Good - Good working order, requiring only nominal or infrequent minor repairs (more than 6 months).
- o Excellent - Brand new, no major problems exist, only routine preventative maintenance.

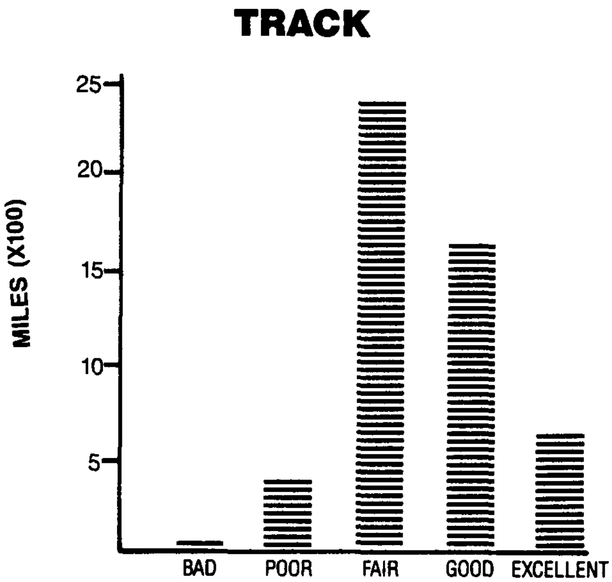
General aggregate findings, with respect to the current condition of each of the major system elements or subsystems in accordance with these definitions, are provided in the following paragraphs. Conditions for each rail transit system follow in Section 3.0.



Deteriorated Fence

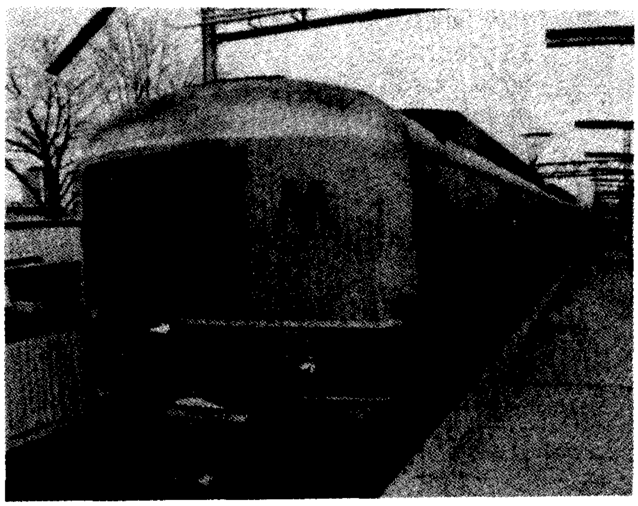
- o Track

The inspected transit systems have 5,102 miles of track, with 28 percent on rapid rail systems, 7 percent on light rail systems, and 65 percent on commuter rail systems. Approximately 12 percent of this track was determined to be in "excellent" condition, 31 percent in "good" condition, 49 percent in "fair" condition, 7 percent in "poor" condition and less than 1 percent in "bad" condition. Since most of the track was less than 45 years old and included in some type of maintenance program, the track has remained in a "fair" or better condition for a reasonably long period of time (i.e., beyond 40 years).



- o Vehicles - Self-Propelled Rail Cars

The inspected transit systems' fleets consist of 12,963 self-propelled rail cars with 74 percent of these on rapid rail systems, 7 percent on light rail systems and 19 percent on commuter rail systems.
Approximately 7 percent of these rail cars were determined to be in "excellent" condition, 28 percent in "good" condition, 18 percent in "fair" condition and 47 percent in either "poor" or "bad" condition. Most of the rail cars in "bad"



M-2 Self-Propelled Commuter Rail Car

condition were more than 20 years old. Although most of the self-propelled rail cars were included in a maintenance program, they still deteriorated to a "poor" condition in 20 to 30 years.

o Vehicles - Locomotives

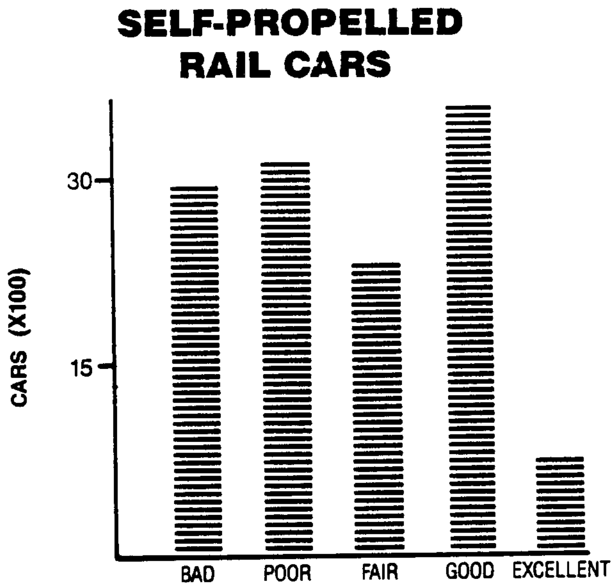
The inspected transit systems' fleets consist of 416 locomotives, all on the commuter rail systems. Approximately 49 percent of these locomotives were in "good" condition, 35 percent in "fair" condition, 13 percent in "poor" condition and 3 percent in "bad" condition. All of the locomotives in "bad" condition were over 22 years old; however, some deteriorated to a "poor" condition in about 10 years depending upon the type of maintenance program.

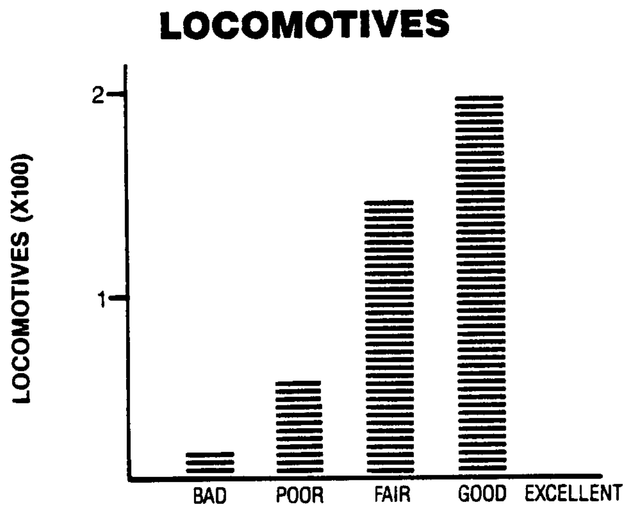
o Vehicles - Unpowered Cars

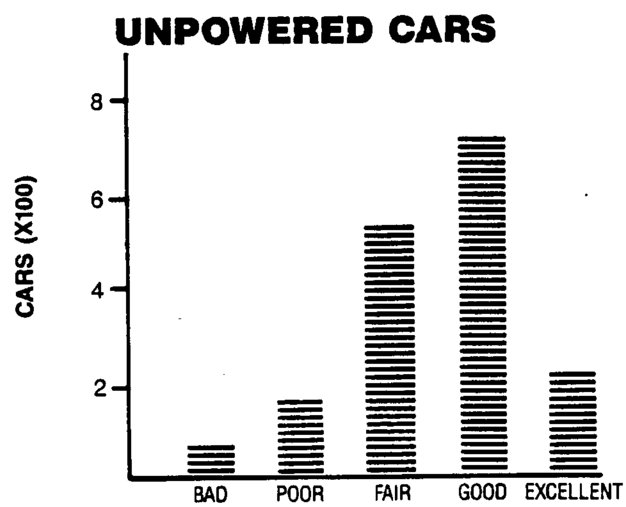
The inspected transit systems' fleets consist of 1,671 unpowered cars and these were all located on the commuter rail systems. Approximately 12 percent. of these unpowered cars were determined to be in "excellent" condition, 43 percent in "good" condition, 32 percent in "fair" condition, 10 percent in "poor" condition, and 3 percent in "bad" condition. Most of the unpowered cars were less than 15 years old, but some deteriorated to a "bad" condition in less than 10 years. However, most of the unpowered cars in "bad" condition were over 30 years old.

o Power Distribution - Substations

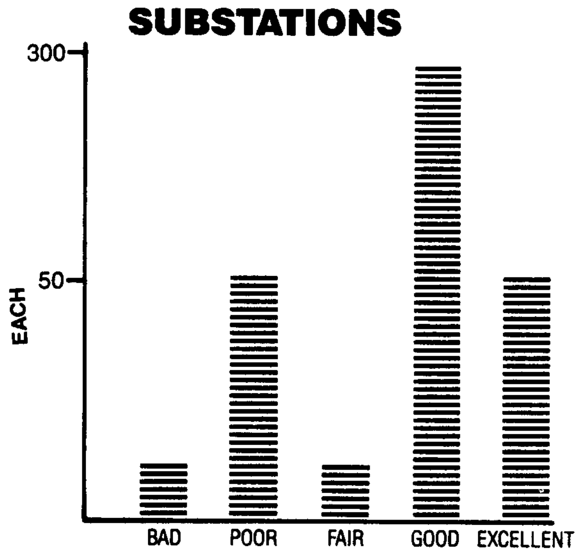
The inspected transit systems have 673 power distribution substations, with 68 percent located on rapid rail systems, 9 percent on light rail systems and 23 percent on commuter rail systems. The inspection





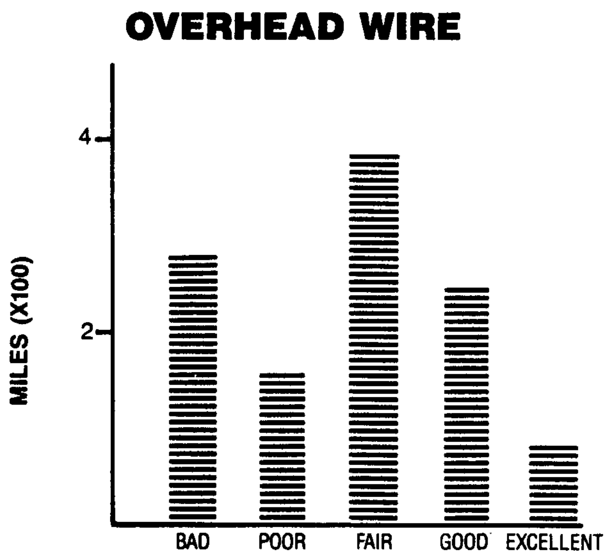


determined that 23 percent of these substations were in "excellent" condition, 43 percent in "good" condition, 5 percent in "fair" condition, 23 percent in "poor" condition and 6 percent in "bad" condition. More than 100 substations were over 50 years old, and most of these were in "poor" or worse condition. However, almost all of the power substations were found to be included in a maintenance program and the rate of deterioration was minimal (i.e., some in "fair" condition were over 50 years old).



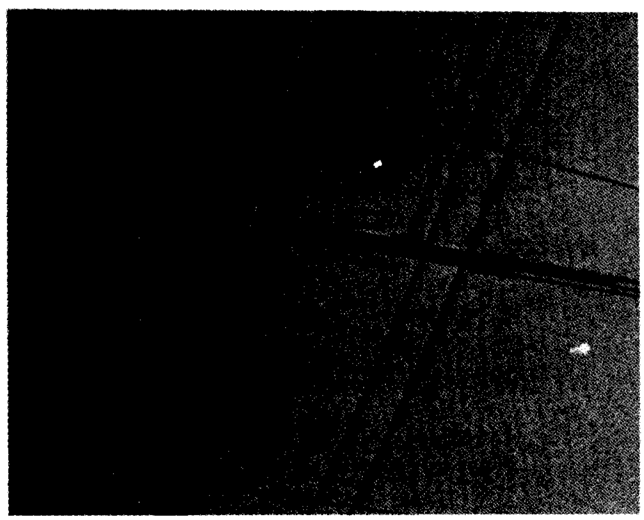
- Power Distribution - Overhead Wire

The inspected transit systems have 1,351 miles of overhead wire; 5 percent was on rapid rail systems, 35 percent on light rail systems, and 60 percent on commuter rail systems. The inspection determined that 5 percent of this overhead wire was in "excellent" condition, 36 percent in "good" condition, 27 percent in "fair" condition, 12 percent in "poor" condition, and 20 percent in "bad" condition. All of the wire in "bad" condition was over 50 years old (275 miles). However, all of the overhead wire was included in a maintenance program and some wire was still in "fair" condition that was more than 50 years old.



- Power Distribution - Third Rail

The inspected transit systems have 1,895 miles of third rail; 73 percent of this third rail was located on rapid rail systems, 1 percent on light rail systems, and 26 percent on commuter rail systems. The inspection determined that approximately 6 percent of this third rail was in "excellent" condition, 36 percent in "good" condition, 19 percent in "fair"



D.C. Feeders Connected to Catenary System condition, 26 percent in "poor" condition and 13 percent in "bad" condition. None of the third rail in "bad" condition was less than 25 years old. Nearly 95 percent of the third rail was included in some type of maintenance program.

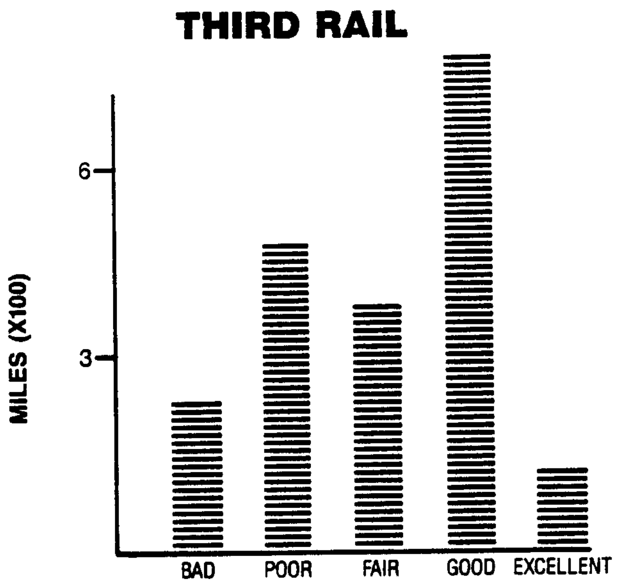
- Stations

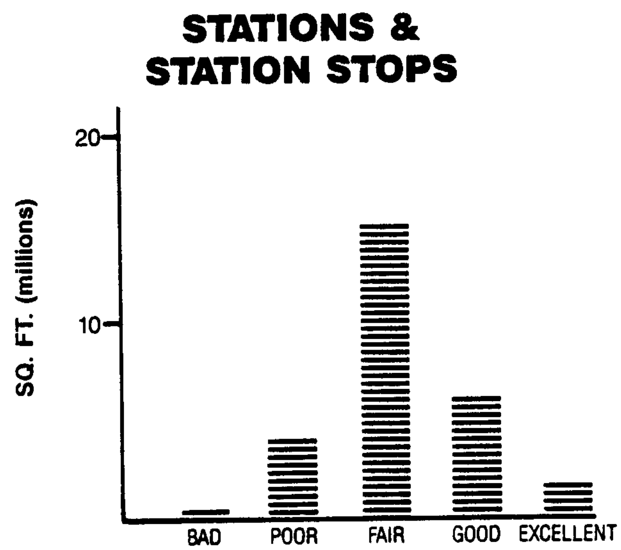
The inspected transit systems have 1,582 stations and 644 station stops. A "station stop" is defined as a minimal track-side facility, usually at-grade, and lacking any extensive structure. A station, on the other hand, is anything else, from above-ground buildings and platforms to complex subway terminals. These stations and station stops contain approximately 27.7 million square feet of area and 78 percent of this area was located on the rapid rail systems, 4 percent on light rail systems, and 18 percent on commuter rail systems. The inspection determined that 6 percent was in "excellent" condition, 23 percent in "good" condition, 56 percent in "fair" condition, 15 percent in "poor" condition, and less than 1 percent in "bad" condition. More than 1,190 stations were more than 50 years old, but some of these were still in "excellent" condition (6 stations). However, some stations were in "poor" condition that were less than 40 years old. Approximately 40 percent of the stations were included in a maintenance program, but about the same number receive "minimal" maintenance.

- Structures and Facilities -Bridges

The inspected transit system bridges were divided into the following two types for purposes of discussion:

- Bridges (Excluding Elevated Railways)
- Elevated Railways





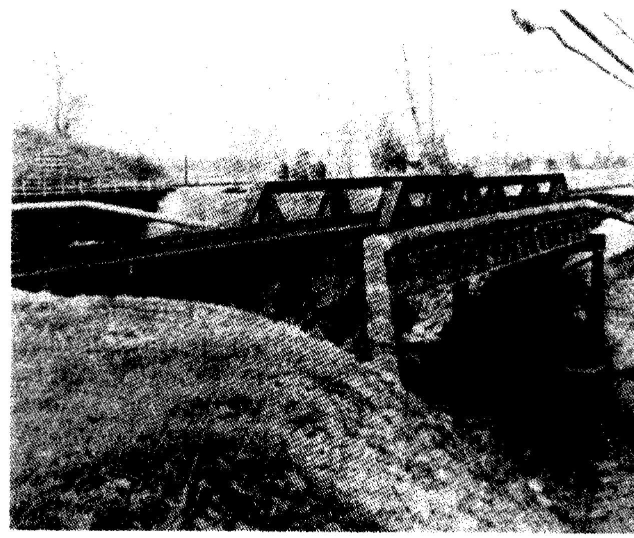
- Bridges (Excluding Elevated Railways)

These bridges contain approximately 11.4 million square feet of area and 16 percent of this area was located on rapid rail systems, 3 percent on light systems and 81 percent on commuter rail systems. The inspection determined that 4 percent of this bridge area was in "excellent" condition, 28 percent in "good" condition, 51 percent in "fair" condition, 16 percent in "poor" condition and 1 percent in "bad" condition.

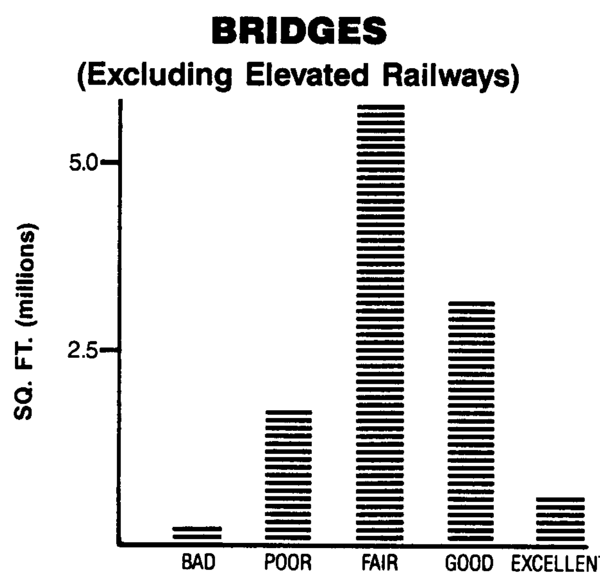
- Elevated Railways

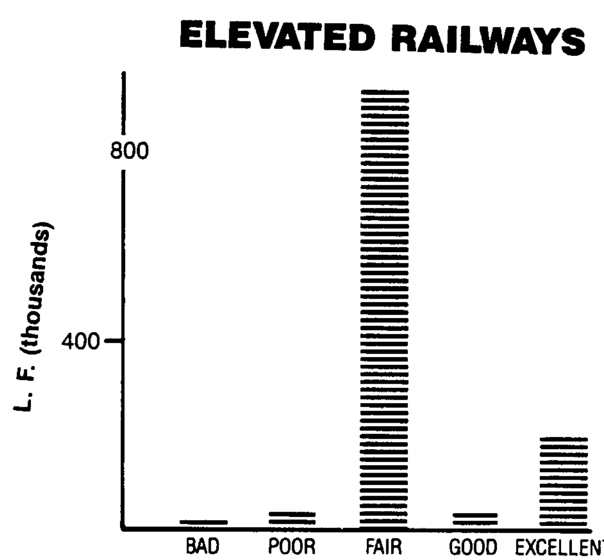
The elevated railways amount to about 1.2 million lineal feet of railway, and 92 percent of this length is located on rapid rail systems, less than 1 percent on light rail systems and approximately 8 percent on commuter rail systems. The inspection determined that 16 percent of this railway was in "excellent" condition, 3 percent in "good" condition, 80 percent in "fair" condition, 1 percent in "poor" condition, and less than 1 percent in "bad" condition.

Over 1,000 bridges were more than 75 years old, but some of these bridges were still in "good" condition. Less than 25 percent of the bridges were included in a recognizable maintenance program; however, the rate of deterioration did not appear to be dependent upon the type of maintenance program.



Through Truss Bridge



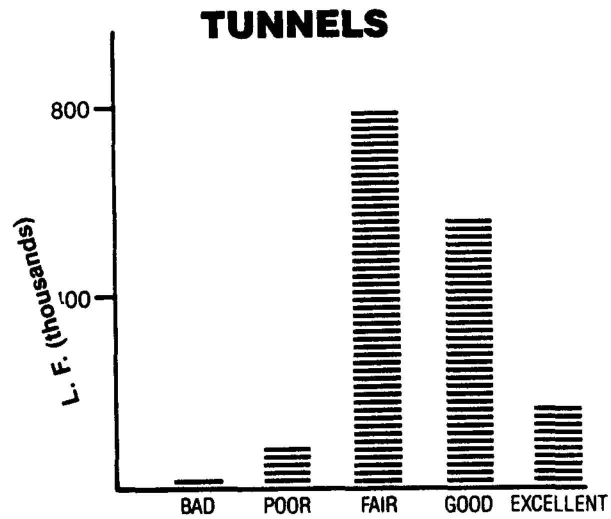


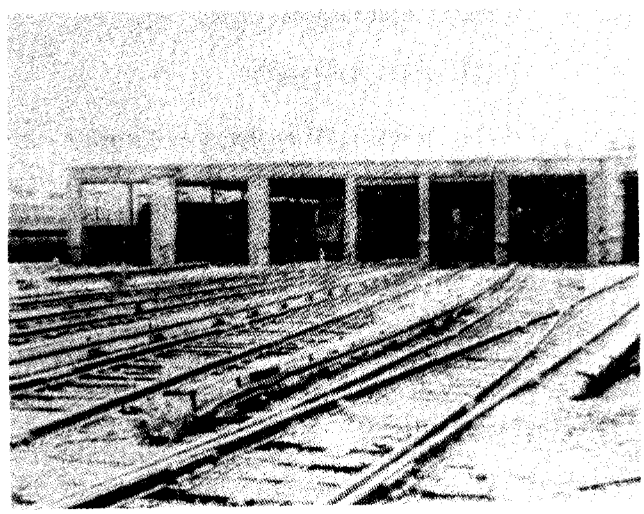
o Structures and Facilities -Tunnels

The inspected transit systems have about 1.66 million lineal feet of tunnels. Approximately 92 percent of this length is located on rapid rail systems, 4 percent on light rail systems and 4 percent on commuter rail systems. The inspection determined that approximately 11 percent of this length of tunnel was in "excellent" condition, 35 percent in "good" condition, 49 percent in "fair" condition, 5 percent in "poor" condition, and less than 1 percent was in "bad" condition. Most of the tunnels, in terms of length, were over 55 years old. Some tunnels were still in "fair" condition even after 100 years, with a minimum of maintenance.

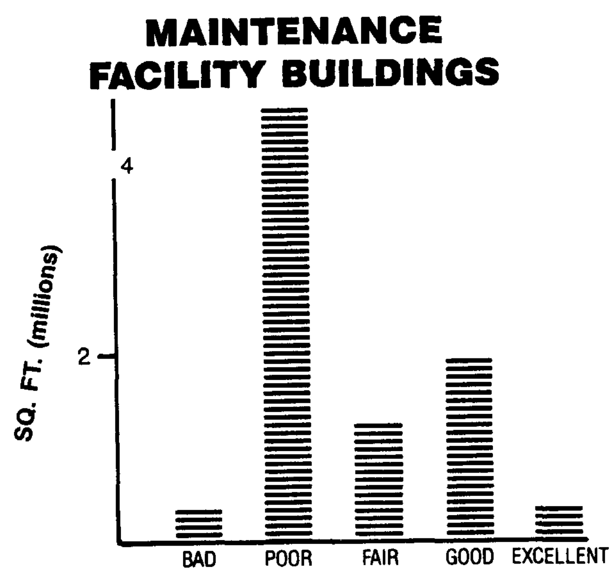
o Maintenance Facility Buildings

The inspected transit systems have 153 major maintenance facility buildings and these buildings contain almost 8.6 million square feet of area. Approximately 62 percent of this area is located on rapid rail systems, 9 percent on light rail systems, and 29 percent on commuter rail systems. Inspection determined that approximately 4 percent of this area was in "excellent" condition, 24 percent in "good" condition, 14 percent in "fair" condition, 54 percent in "poor" condition and 4 percent in "bad" condition. The largest number of maintenance facility buildings were over 50 years old and most of those were in "poor" or "bad" condition. Less than 25 percent of the buildings were included in a maintenance program and most of the buildings receive only minimum maintenance.



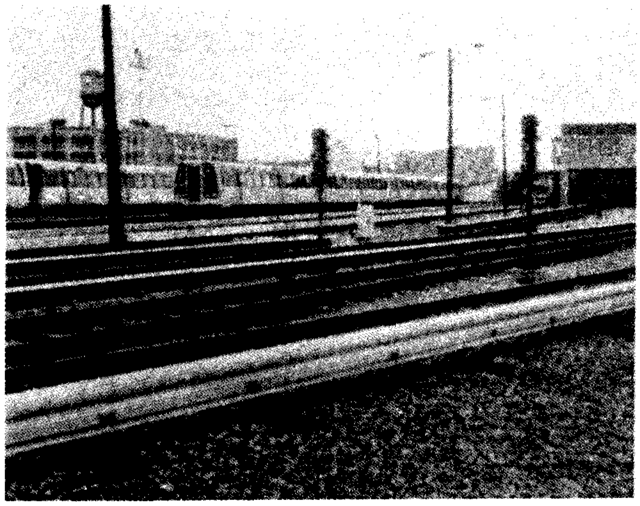


Car House

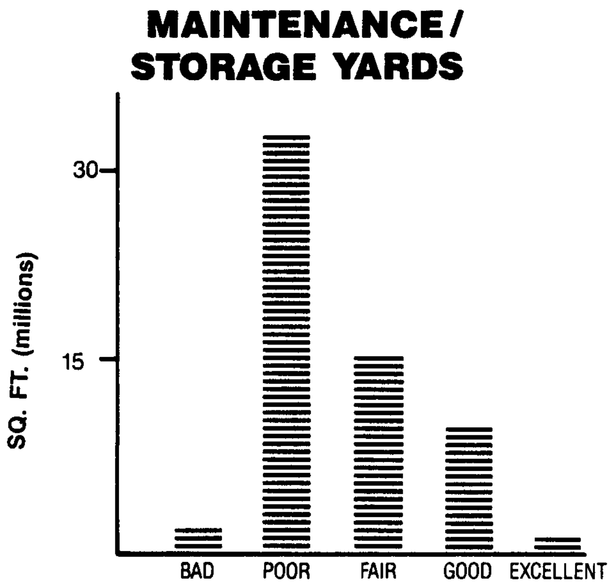


o Maintenance/Storage Yards

The inspected transit systems have 132 maintenance/storage yards. These yards included almost 63 million square feet of area. Approximately 56 percent of this area was located on rapid rail systems, 4 percent on light rail systems and 40 percent on commuter rail systems. The inspection determined that about 1 percent of this area was in "excellent" condition, 16 percent in "good" condition, 26 percent in "fair" condition and 57 percent in either "poor" or "bad" condition. More than 80 of the maintenance facility storage yards were over 50 years old and most of these yards were in "poor" or "bad" condition. Less than 20 percent of the yards were included in a maintenance program and most receive only minimum maintenance.



Maintenance/Storage Yard



1.9 SUMMARY OF PROPOSED REPAIR AND REPLACEMENT ACTIONS (MODERNIZATION, REHABILITATION, AND REFURBISHMENT)

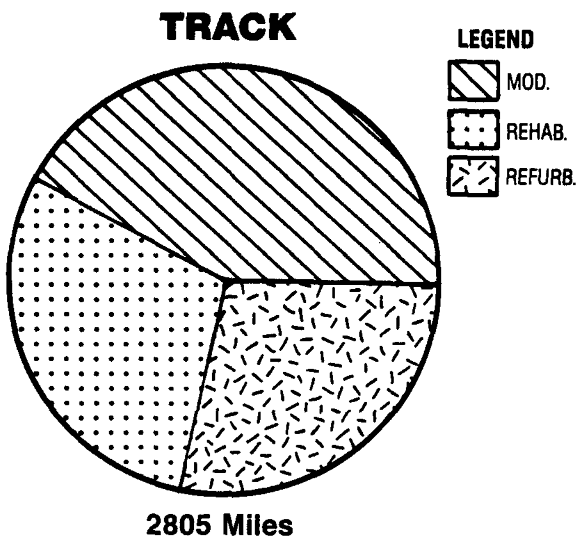
The general procedure for defining and estimating rail improvement projects was explained in Section 1.7. Three categories of improvement were established: modernization, rehabilitation and refurbishment. After the current condition was established, an appropriate level of improvement to bring all elements to "good" or better condition, if feasible, was determined. Three levels of modernization were defined for this study, two levels of rehabilitation and two levels of refurbishment. Each level may involve the replacement of subsystems, components, and equipment with the type of replacement dictated by the degree of improvement. That is, modernization is the use of proven new materials, components or subsystems to achieve higher standards of performance or productivity than original equipment; rehabilitation is the replacement of worn materials, subsystems, and components with items having basically the same design and function as the original equipment; and refurbishment is the restoration or correction of deficiencies of subsystems and components to adequate levels of performance.

The general findings for some elements and subsystems, with respect to the proposed category of improvement are provided in the following paragraphs. These findings provide the basis for the development of capital costs in the next section of this report.

New Continuous Welded Rail

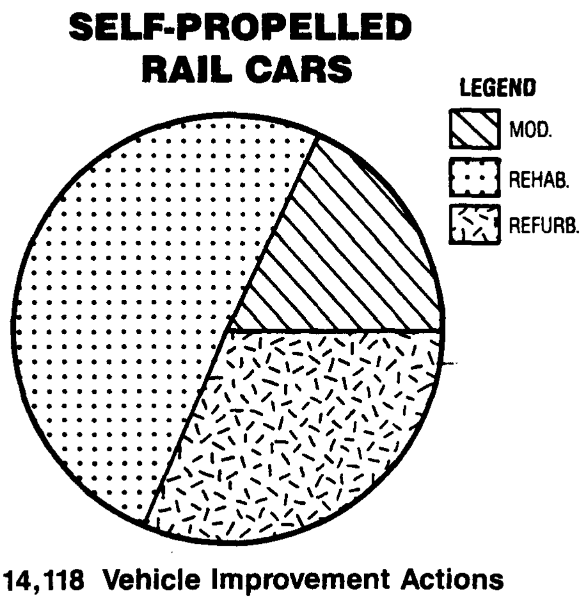
- o Track

The inspected transit systems have 5,102 miles of track, and it was determined that 2,805 of these miles would require some type of improvement during the next 10 years to return all track to "good" condition. Sixteen percent of the track requiring improvement was located on rapid rail systems, 5 percent on light rail systems and 79 percent on commuter rail systems. The inspection concluded that 44 percent of this track required modernization, 31 percent rehabilitation and 25 percent refurbishment.



- o Vehicles - Self-Propelled Rail Cars

The inspected transit systems' fleets consist of 12,963 self-propelled rail cars. It was determined that 14,118 improvement actions would be required for these rail cars to return all to "good" condition. Seventy-six percent of these improvements were required on rapid rail systems, 6 percent on light rail systems, and 18 percent on commuter rail systems. The inspection concluded that 18 percent of these improvements entail modernization, 51 percent rehabilitation and 31 percent refurbishment.



o Vehicles - Locomotives

The inspected transit systems' fleets consist of 416 locomotives, and it was determined that 395 locomotive improvement actions would be required during the next 10 years to return all to "good" condition. It was determined that 28 percent of these improvements would require modernization, 65 percent rehabilitation and only 7 percent refurbishment.

o Vehicles - Unpowered Cars

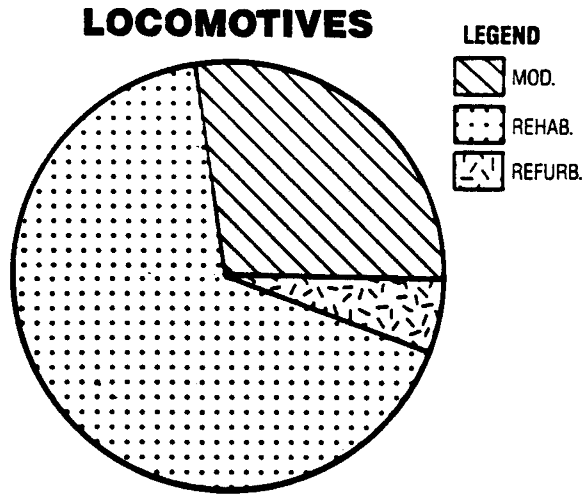
The inspected transit systems' fleets consist of 1,671 unpowered cars, and it was determined that 1,633 unpowered car improvement actions would be required during the next 10 years to return all to "good" condition. These improvements include 18 percent modernization, 8 percent rehabilitation, and 74 percent refurbishment.

o Power Distribution - Substations

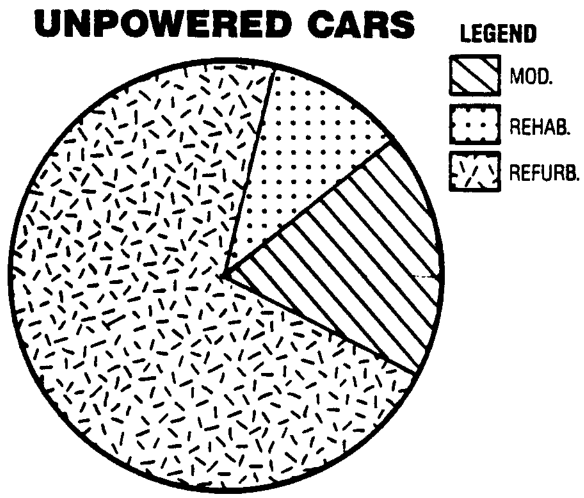
The inspected transit systems have 673 power distribution substations and it was determined that 193 of these substations would require some type of improvement during the next 10 years to return all to "good" condition. Eighty-five percent of these substations requiring improvement were located on rapid rail systems, 4 percent on light rail systems, and 11 percent on commuter rail systems. It was determined that 65 percent of these improvements would require modernization, 4 percent rehabilitation and 31 percent refurbishment.

o Power Distribution - Overhead Wire

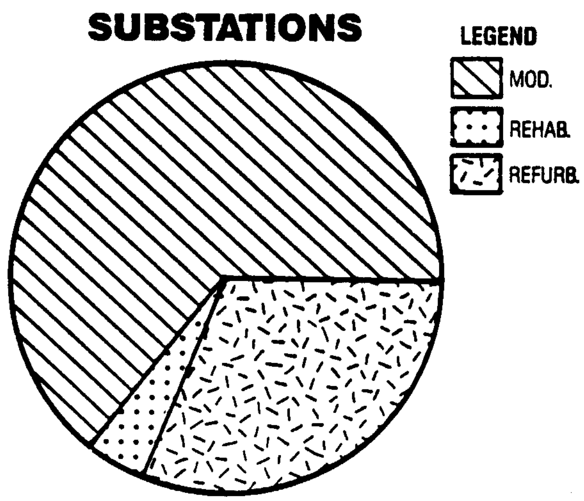
The inspected transit systems have 1,351 miles of overhead wire and it was determined that 761 miles of



395 Locomotive Improvement Actions



1633 Car Improvement Actions



193 Substations

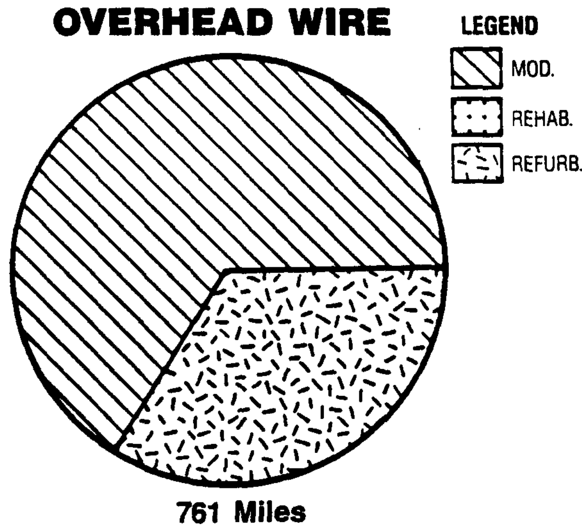
this wire would require some type of improvement during the next 10 years to return all to "good" condition. One percent of this wire requiring improvement was located on rapid rail systems, 14 percent on light rail systems and 85 percent on commuter rail systems. It was also determined that 66 percent of this wire would require modernization and 34 percent refurbishment.

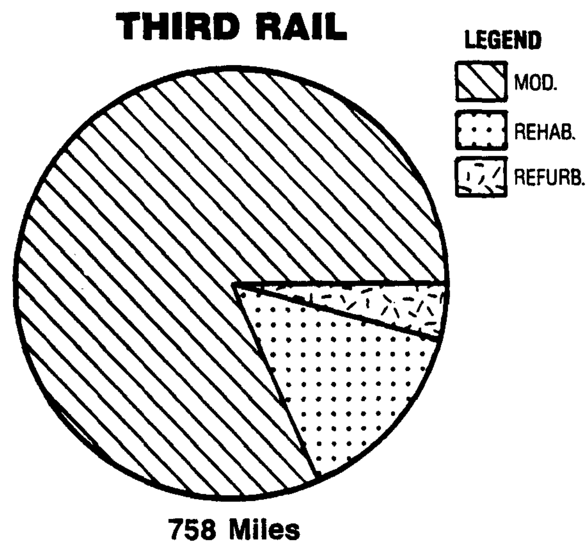
o Power Distribution - Third Rail

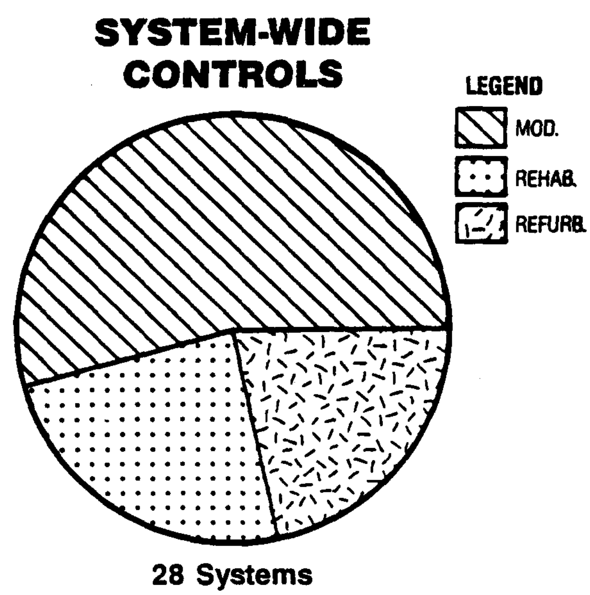
The inspected transit systems have 1,895 miles of third rail and it was determined that 758 miles would require some type of improvement during the next 10 years to return all to "good" condition. Of the third rail requiring improvement, 63 percent is located on rapid rail systems, 3 percent on light rail systems, and 34 percent on commuter rail systems. It was determined that 82 percent of this rail would require modernization, 14 percent rehabilitation and 4 percent refurbishment.

o System-Wide Controls

The inspected transit systems have 29 system-wide control systems and 28 of these will require some type of improvement during the next 10 years to return all to "good" condition. Approximately 39 percent of these systems requiring improvement are located on rapid rail systems, 22 percent on light rail systems and the remaining 39 percent on commuter rail systems. The evaluation determined that 54 percent of these system-wide control systems would require modernization, 25 percent rehabilitation and 21 percent refurbishment.







- o Stations

The inspected transit systems have 1,582 stations and 644 station stops; these stations contain approximately 27.7 million square feet of area. The inspection determined that about 24.5 million square feet of station and station stop area would require some type of improvement during the next 10 years to return all to "good" condition. Nearly 80 percent of this station area was in rapid rail stations, 3 percent in light rail stations and 17 percent in commuter rail stations. Approximately 15 percent of the area would require modernization, 41 percent rehabilitation and 44 percent refurbishment.

- o Structures and Facilities -Bridges

The inspected transit system bridges were divided into two types for the purpose of analysis.

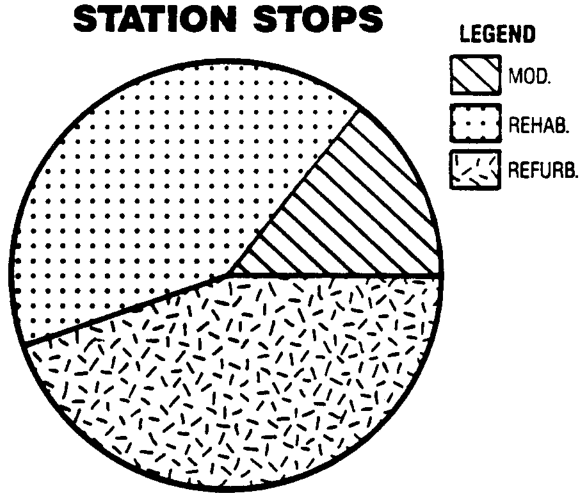
- Bridges (Excluding Elevated Railways)

The inspected transit systems have about 11.4 million square feet of bridge area and it was determined that approximately 10.7 million square feet will require some type of improvement in the next 10 years to leave all in "good" condition. About 14 percent of the bridge area which would have to be replaced is located on rapid rail systems, 2 percent on light rail systems, and 84 percent on commuter rail systems. It was also determined that 1 percent of this bridge area would require modernization, 67 percent rehabilitation and 32 percent refurbishment.

- Elevated Railways

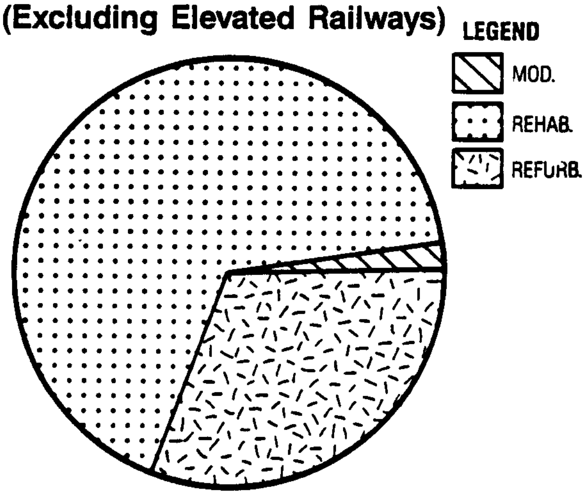
The inspected transit systems include about 1.2 million lineal feet of elevated railway and it

STATIONS & STATION STOPS



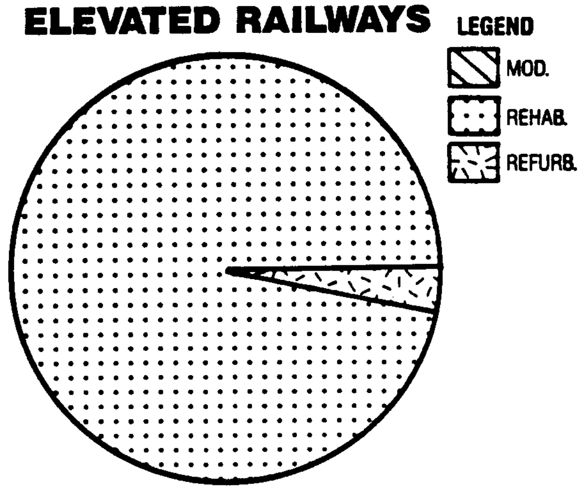
24.5 Million $Ft.^2$

BRIDGES
(Excluding Elevated Railways)



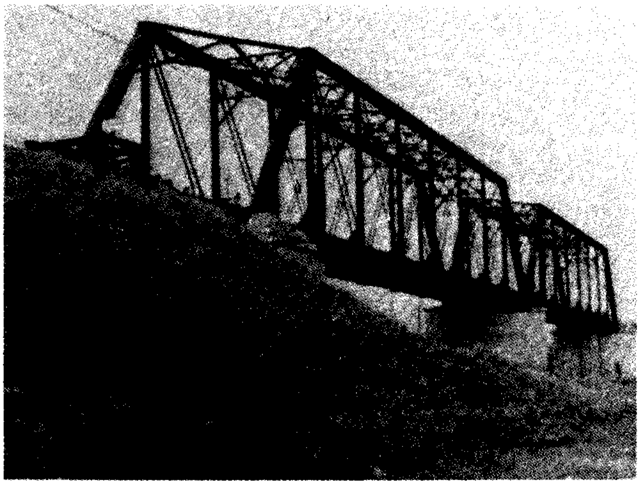
10.7 Million $Ft.^2$

ELEVATED RAILWAYS



979 Thousand L.F.

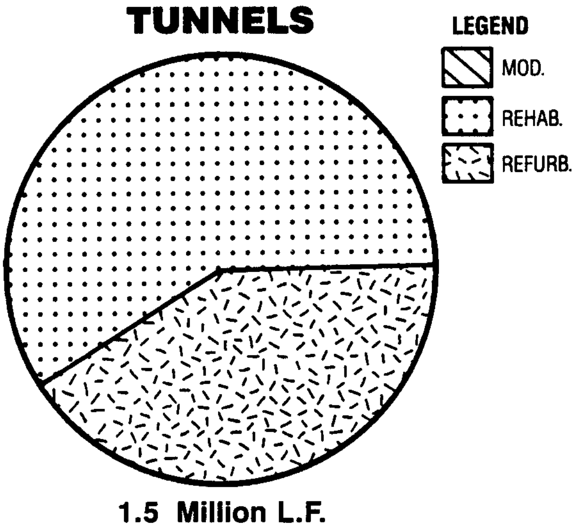
was determined that 980,000 lineal feet would require some type of improvement in the next 10 years to leave all in "good" condition. Nearly 92 percent of this elevated railway was located on rapid rail systems, 1 percent on light rail systems, and the remaining 7 percent on commuter rail systems. The inspection also determined that less than 1 percent of the length of elevated railway would require modernization, 97 percent rehabilitation and 3 percent refurbishment.



Through Truss Bridge

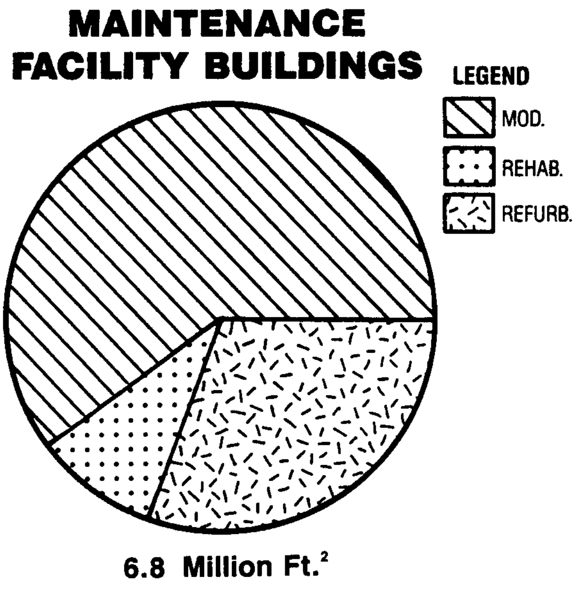
o Structures and Facilities -Tunnels

The inspected transit systems have about 134 tunnels, which are about 1.6 million lineal feet in length. The inspection determined that about 1.5 million lineal feet would require some type of improvement during the next 10 years to leave all in "good" condition. Approximately 92 percent of this length was located on rapid rail systems, 3 percent on light rail systems and 5 percent on commuter rail systems. The inspection also determined that 1 percent of this length of tunnel would require modernization, 59 percent rehabilitation, and 40 percent refurbishment.



o Maintenance Facility Buildings

The inspected transit systems have 153 maintenance facility buildings, which include 8.6 million square feet of area. The inspection determined that about 6.8 million square feet of maintenance facility building area would require some type of improvement during the next 10 years to leave all in "good" condition. About 52 percent of this maintenance facility building area is located on rapid rail systems, 10 percent on light rail systems, and 38



percent on commuter rail systems. The inspection also determined that 63 percent of this area would require modernization, 10 percent rehabilitation and the remaining 27 percent refurbishment.

- Maintenance/Storage Yards

  The inspected transit systems have 132 maintenance/storage yards which contain almost 63 million square feet of area. The inspection determined that more than 52 million square feet of maintenance/storage yards would require improvement during the next 10 years to leave all in "good" condition. About 51 percent of this area is located on rapid rail systems, 4 percent on light rail systems, and 45 percent on commuter rail systems. The inspection also determined that about 66 percent of this area would require modernization, 13 percent rehabilitation, and the remaining 21 percent refurbishment.

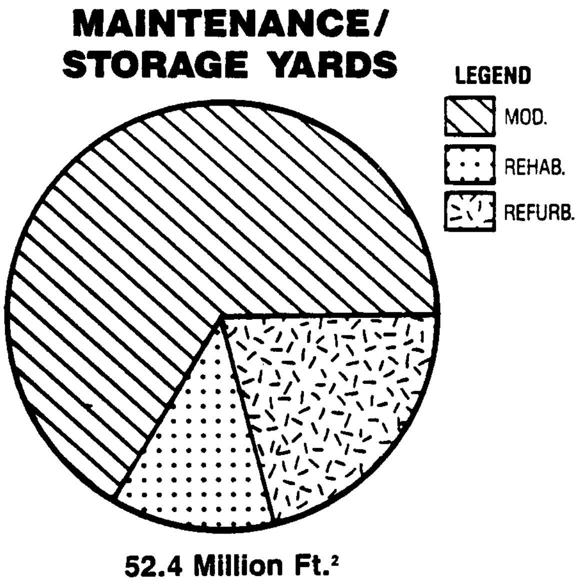
1.10 PROCEDURES FOR ESTIMATING COSTS AND BENEFITS

1.10.1 COST ESTIMATION

Standard engineering cost estimation techniques were used to develop the costs for each improvement project. This involved calculation of the quantities involved and application of unit cost data obtained for each city from published sources. The result was an estimate of costs for each improvement on each transit system. Costs were estimated in 1983 dollars and thus do not account for inflation.

1.10.2 ESTIMATION OF BENEFITS

Several steps were required in order to assess the benefits associated with each improvement project:



- <u>Establishment of System Segments</u>. Although improvement projects were formulated separately for each element in the system, the transit authorities would more likely implement such improvements on a segment basis. Therefore, it was necessary to divide each system into appropriate segments so that the cost-effectiveness of rehabilitating each segment could be estimated. Division points between the segments were chosen to coincide with major breaks in service level (e.g., branch points, breaks between diesel and electric commuter rail operation, etc.).

- <u>Estimation of Passenger Miles</u>. Identification of the segments was followed by estimation of the passenger miles for each segment. A method was developed which used station utilization (utilization was calculated at each transit system during the site visits), track miles and the number of stations to estimate passenger miles for each transit system. The estimates were normalized at the system level to the values reported in 1983 in the Section 15 data system, and were then calculated for each segment.

- Identification of Segment Improvements. Since improvements were first identified on a system-wide basis, it was necessary to allocate improvement costs and quantities to appropriate segments. The result of this disaggregation was assignment of quantities and costs to each segment/branch along with the associated present condition, change in condition, and age of each system element/subsystem.

- Assessment of Benefits. Once improvements were established for each segment, the next step was assessment of the benefits associated with each improvement which was expressed in terms of two measures: passenger miles served and net social benefits, the latter calculated by applying a method developed by LTI. Details of the benefit assessment are described in Chapter 5 and in the Appendix to this report.

1.10.3 BENEFITS OF RAIL MODERNIZATION IMPROVEMENTS

The basis for the benefit estimation technique used in this study is the hypothesis that the benefits of rail modernization improvements ultimately are a combination of operating cost savings and passenger travel time savings. Essentially, all rail modernization improvement actions are designed to improve the performance of the rail system. For example, a track improvement project may allow trains to operate at a higher speed. However, this change in performance is not, per se, the benefit of the improvement. Only if the change in performance can actually translate into an improvement in the level of service that the passenger faces, or a reduction in the cost of providing service to the transit operator, is a real economic benefit achieved. In the case of a track improvement project, an increase in speed could translate into faster trips for passengers, reducing the "cost" of the trip to them in terms of the travel time they must expend to make a trip. Alternatively, the increase in speed could allow the transit operator to provide the same service interval ("headway") with fewer trains, reducing operating and capital costs and the need to maintain additional equipment.

- Benefits in Terms of Utilization. The first method used to assess the relative cost-effectiveness of the proposed segment improvements was to calculate benefits in terms of the passenger miles served by the segment. This measure can be thought of as the cost per passenger mile of use to restore all aspects of service to "good" condition. It represents a basic measure of the benefits of the improvements proposed since any benefits which result from the improvements will do so only to the extent that the service provided is utilized.

- Assessing the Value of the Net Social Benefits. In order to more completely account for the benefits of the rail modernization improvements, a method was developed by LTI to estimate values for the operating cost and user travel time savings which would be achieved for each subsystem improved depending on its condition before and after the improvement. To the extent possible, the unit values selected were based on performance data collected during site visits. In cases where such data was not available or was not collected by the transit authority on a sufficiently uniform basis to allow estimates to be made of the effect of improvements and their related condition changes, the experience of LTI in making similar improvements to the rail systems in London was applied, adjusted for typical United States total costs, experiences and practices. The values developed are averages based on typical service levels. That is, they assumed normal operating patterns for various types of rail systems.

- Limitation. One of the limitations of this approach to benefit/cost estimation is that there is no explicit treatment of alternatives. Hence the benefits of maintaining rail service instead of replacing it with bus service (where not making the improvement would require abandonment, because of, perhaps unsafe conditions) are not estimated. Nor is there any treatment of alternative levels of capital investments. For a more complete analysis, each segment should be evaluated in terms of a continuum of improvements as well as against various "no-improvement" alternatives (i.e., abandonment, with and without service replacement). With the full costs and benefits of each of these alternatives established a more completely informed decision about each segment can be made. While such a complete analysis is well beyond the scope of this study, the results of the method used here demonstrate that the segments have such different cost/benefit ratios that an analysis of this type would be warranted in many local circumstances, particularly for those segments showing lower cost/benefit ratios in relative terms.

1.11 TOTAL ESTIMATED COST FOR ALL SEGMENTS

Presented below are the estimated total costs for all 34 transit systems. Summaries by types of transit systems, by category of improvement, by system elements, and by system elements for each category of improvement are provided.

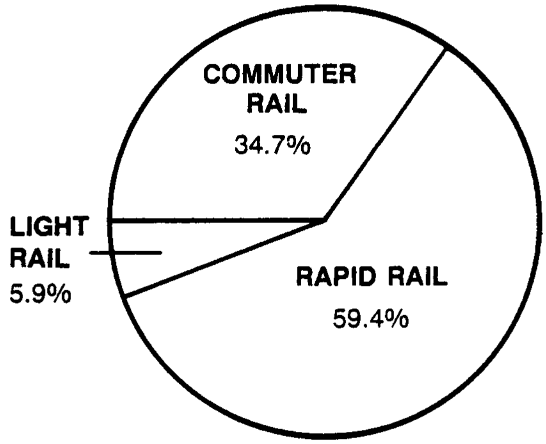
- Types of Transit Systems

The distribution of estimated capital costs among the types of transit systems is as follows:

	$-Billions
Rapid Rail	10.620
Light Rail	1.052
Commuter Rail	6.204
Total	17.876

The preponderance of costs would be for the rapid rail systems (59.4 percent), followed by commuter rail (34.7 percent) and light rail (5.9 percent).

DISTRIBUTION BY TYPES OF SYSTEMS



- Categories of Improvement

The categories of improvement required to upgrade all segments of the systems are as follows:

	$-Billions
Modernization	8.526
Rehabilitation	7.502
Refurbishment	1.848
Total	17.876

Nearly 90 percent of the estimated costs are required to modernize and rehabilitate rail facilities and equipment. The current condition of the system elements requiring refurbishment only is such that slightly more than 10 percent of total capital costs could be effectively used to achieve appropriate standards (i.e., good or excellent condition).

o System Elements

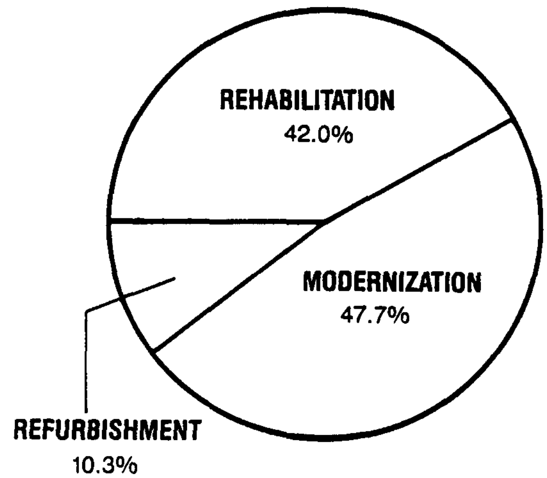
The capital costs for each of the seven system elements for all of the transit system segments are summarized below:

	$-Billions
Track	1.900
Vehicles	3.372
Power Distribution	1.578
System-Wide Controls	2.699
Stations	3.197
Structures and Fac.	3.544
Maintenance Fac.	1.586
Total	17.876

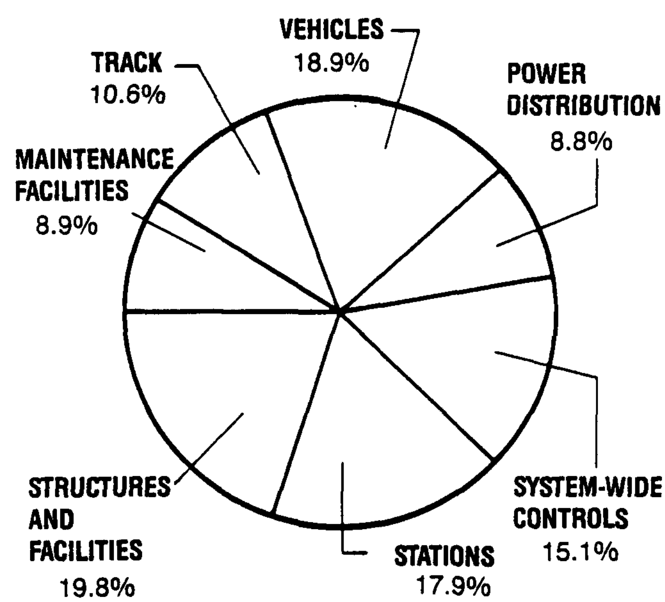
The greatest cost is for upgrading structures and facilities (bridges and tunnels). But capital costs for improving vehicles, stations and system-wide controls are only slightly less.

The lower capital costs for improvements to the track and power distribution elements reflect the fact that both of these elements are absolutely essential to system operations. Hence, over the years they have been subject to better maintenance and more extensive capital replacement than have some of the other system elements. The comparatively lower costs for power distribution improvements also reflect the fact that commuter rail service is powered by diesel locomotives as well as by electric traction.

CATEGORIES OF IMPROVEMENT



SYSTEM ELEMENTS



o System Elements by Type of Transit System

For all segments of the rapid, light and commuter rail systems, the distribution of estimated capital costs for the 7 system elements is provided in Table 1.5. An evaluation of these costs follows.

- Track

The relatively low cost of capital improvements for rapid rail trackage reflects current cyclical replacement programs practiced by most rapid transit authorities. Nearly 90 percent of such track is in "fair" or better condition.

Although no light rail track is in "bad" condition, nearly 37 percent was found to be in "poor" condition. Nearly 98 percent of the commuter rail track is in "fair" or better condition. The comparatively higher estimated costs for commuter rail track improvements are attributed to the great amount of track—more than twice that of the rapid rail systems.

- Vehicles

Almost one-fifth of capital costs for all rapid rail system improvements are for self-propelled rail cars. More than 64 percent of the vehicles in transit fleets serve the rapid rail systems. More than half the self-propelled cars in the rapid rail fleets were in "poor" or "bad" condition and most of these were more than 15 years old.

Vehicle improvements also comprise the greatest share of all light rail capital costs. Cars represent one of the costliest of light rail elements. More than 43 percent of rail cars in the light rail fleets were judged to be in "bad" or "poor" condition.

Vehicles in the commuter rail fleets, including self-propelled rail cars, locomotives, and unpowered cars, were in better condition than those in the rapid and light rail fleets. More than 68 percent of the self-propelled cars, 85 percent of the locomotives and 86 percent of the unpowered cars were in "fair" or better condition.

Capital improvements which would be required to correct conditions

TABLE 1.5

Total Capital Costs to Rehabilitate Fully the Transit Systems

($-Billions of 1983 Dollars)

System Element	Rapid Rail	Light Rail	Commuter Rail	Total	Percent
Track	0.564	0.194	1.142	1.900	10.6%
Vehicles	1.966	0.374	1.032	3.372	18.9%
Power Distribution	0.881	0.187	0.510	1.578	8.8%
System-Wide Controls	1.704	0.101	0.894	2.699	15.1%
Stations	2.641	0.041	0.515	3.197	17.9%
Structures & Facilities	1.989	0.099	1.456	3.544	19.8%
Maintenance Facilities	0.875	0.056	0.655	1.586	8.9%
Total	10.620	1.052	6.204	17.876	100%
Percent	59.4%	5.9%	34.7%	--	100%

due to the age of these rail cars are indicated in the following table.

Percent of Commuter Rail Vehicles Over 15 Years of Age

Self-Propelled Cars:	45.0%
Locomotives:	21.5%
Unpowered Cars:	25.5%

Many of the vehicles in the worst conditions were already funded for replacement.

- Power Distribution

Power distribution installations on the rapid and light rail systems are generally in better condition than those on the commuter rail systems. Capital improvements on the rapid and light rail systems are primarily concerned with problems of obsolescence and deterioration resulting from intense utilization.

Although less than 45 percent of the commuter rail trackage is electrified, the capital costs reflect the following:

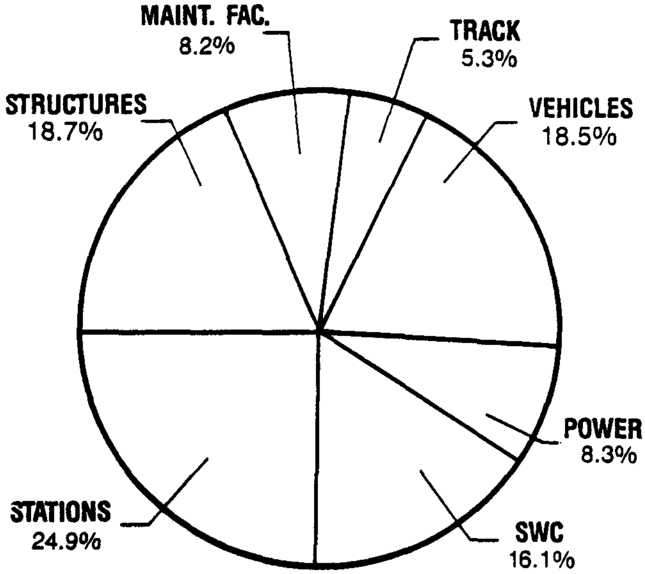
. 39 percent of the substations are poor or bad, and nearly all of these are more than 35 years old.

. Nearly 45 percent of the overhead wire and third rail were in "poor" or "bad" condition.

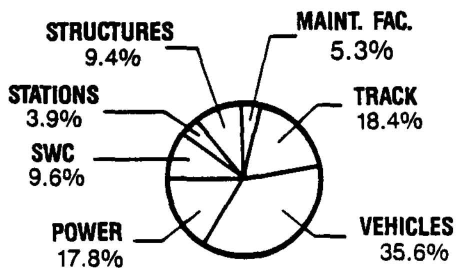
The capital costs for the commuter rail systems also reflect some extensions of electrification on lines where there is now both electric and diesel propulsion.

- System-Wide Controls

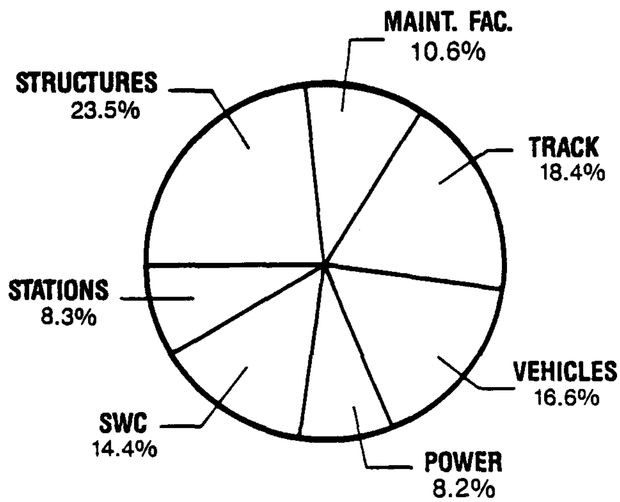
The estimated capital cost of improvements for the light rail systems are relatively less than for the other two types of transit systems because they depend primarily on manual operations. Funding for all three types of



RAPID RAIL



LIGHT RAIL



COMMUTER RAIL

transit systems is associated with upgrading the controls in conjunction with concurrent improvements to tracks and structures.

- Stations

The major requirement for capital improvements in the rapid rail systems is estimated to be for stations. Most of the stations in "poor" or "bad" condition are more than 60 to 70 years old. Minimal maintenance and vandalism have contributed to the cost of upgrading. Stations on the light rail and commuter rail systems are, for the most part, much less complex with proportionately smaller needs for capital improvements.

- Structures and Facilities

Capital costs for improvements to structures and facilities on the light rail systems are the lowest of the three types of systems because there are fewer structures and they are simpler. Requirements for structures and facilities capital investments on the commuter rail systems are high because commuter rail systems have large proportions of the inventory of such assets. For example, commuter rail systems account for 74 percent of all highway bridges, 72 percent of pedestrian overpasses and 96 percent of pedestrian underpasses.

The rapid rail systems have 417 transit bridges (79 percent) and 59 percent of the tunnels. Most of the structures suffer from minimal maintenance and old age. Most transit bridges, in fact, are more than 50 years old; many exceed 75 years of age and some still in regular use are more than 100 years old. Most tunnels exceed 50 years of age; many are more than 75 years of age and some exceed 90-100 years.

- Maintenance Facilities

Universally, these facilities have suffered from age and minimum maintenance practices. More than half of all of the maintenance facility buildings and slightly less than half of all the yards were found to be in either "bad" or "poor" condition. All of the buildings in "bad" condition are more than 25 years old and most in "poor" condition are 25 to 40 years of age. All of the maintenance yards in "bad" condition are more than 25 years old, but some yards in "poor" condition were less than 15 years old.

o System Elements by Categories of Improvement

Table 1.6 indicates the total capital costs for each system element according to the categories of improvement. These are also shown graphically in Figure 1.3. This summary emphasizes the diversity in costs among the different system elements. For power distribution, system-wide controls and maintenance facilities modernization would typically be required because of obsolete facilities and equipment.

The cost of modernization in the track and vehicles elements is also high; primarily to replace items subject to continuing operational wear. The major capital costs of upgrading the stations, structures and related facilities are for rehabilitation.

Operational considerations normally preclude modernization of stations

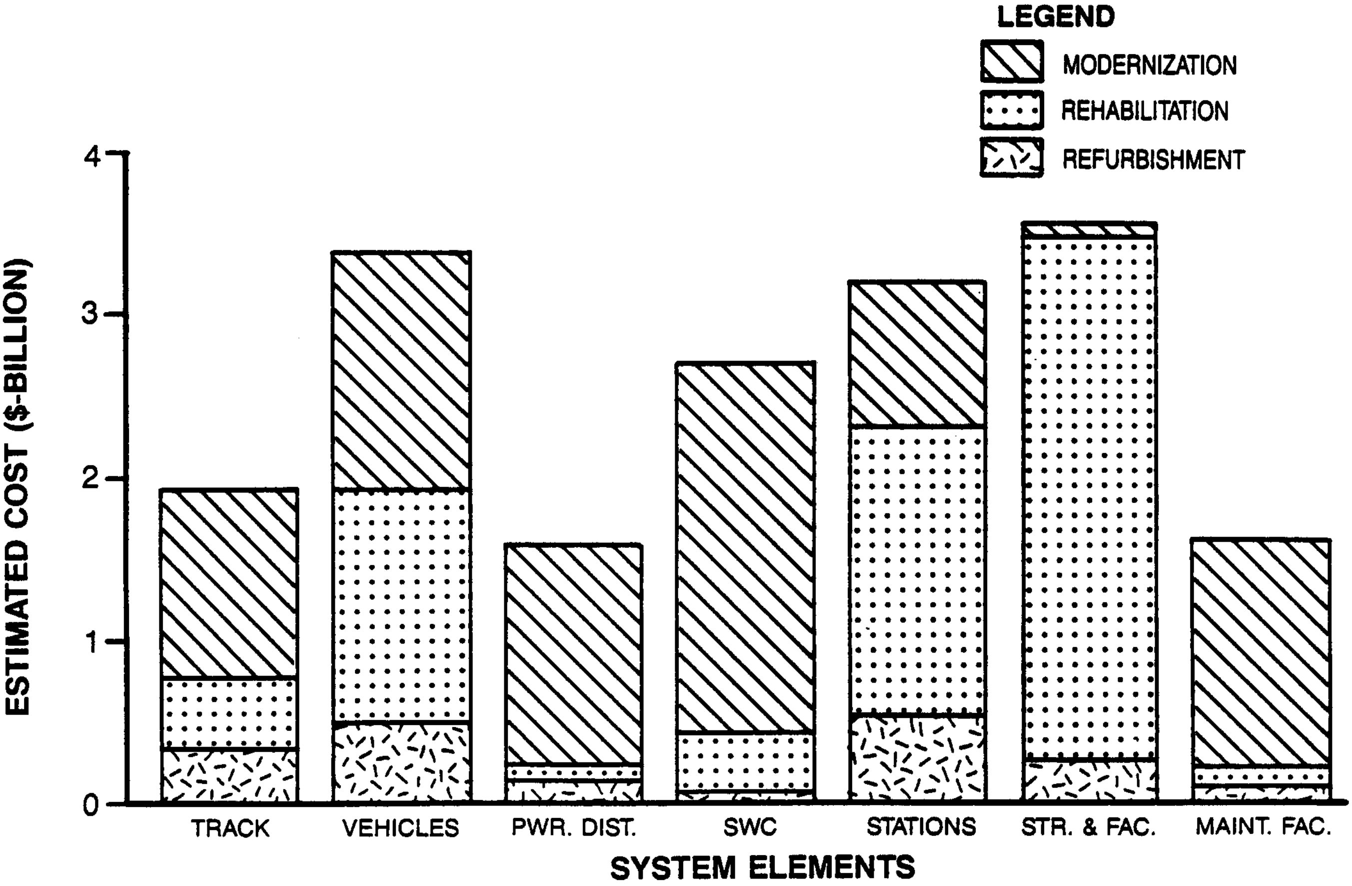
TABLE 1.6

Estimated Cost of System Elements by Categories of Improvement

(1983 Costs in $ Billions)

System Element	Categories of Improvement			Total
	Modernization	Rehabilitation	Refurbishment	
Track	1.120	.446	.334	1.900
Vehicles	1.472	1.406	.494	3.372
Power Dist.	1.349	.104	.125	1.578
SWC	2.266	.374	.059	2.699
Stations	.878	1.813	.506	3.197
Structures	.051	3.257	.236	3.544
Maint. Fac.	1.390	.102	.094	1.586
TOTAL	8.526	7.502	1.848	17.876

FIGURE 1.3
ESTIMATED COSTS OF SYSTEM ELEMENTS BY CATEGORY OF IMPROVEMENT



and structures by replacement or reconstruction. Most stations and structures are sound enough that rehabilitation or refurbishment can usually achieve adequate improvement.

1.12 EXPECTED BENEFITS FOR CAPITAL EXPENDITURE LEVELS

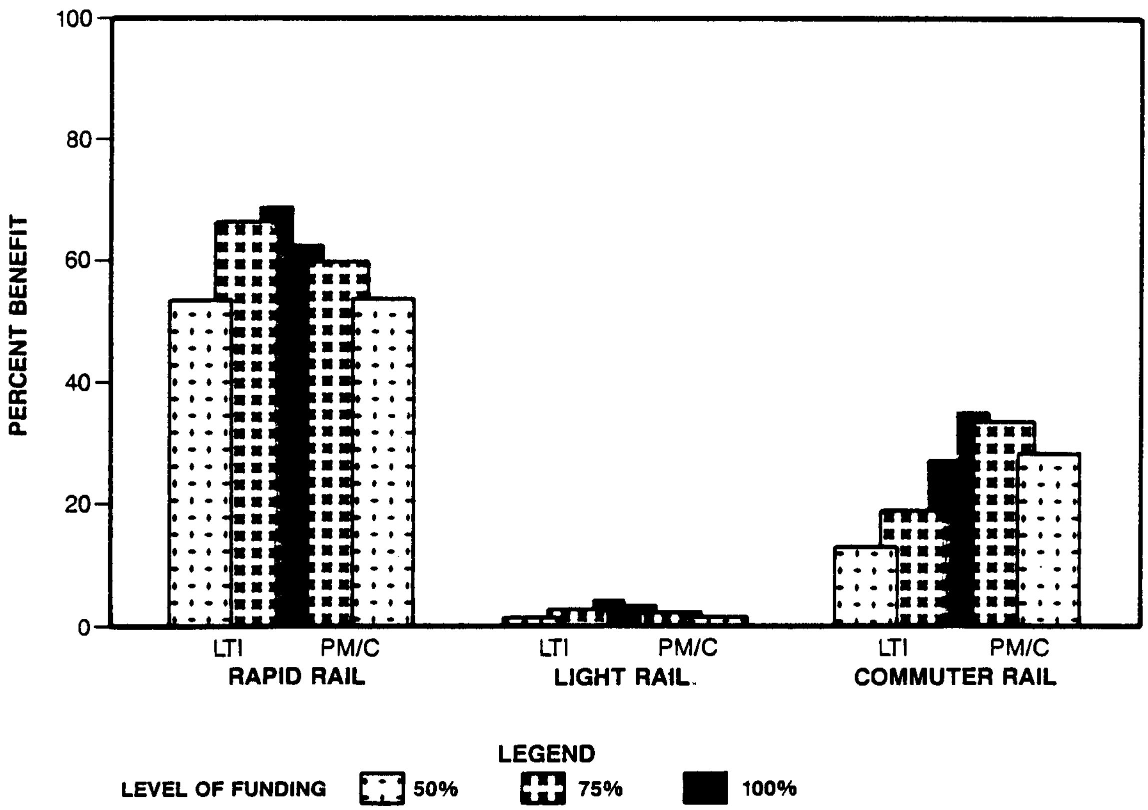
Two methods of assessing the cost effectiveness of the proposed improvements were developed. These methods provide for the "most worthy" rail segment improvements to be accomplished first and some segment improvements to be completed later. The following analysis on the expected benefits for various capital expenditure levels summarizes the results achieved in prioritizing the 186 segments/branches according to benefit/cost ratios, beginning with segments with the highest ratios.

o Benefits by Rail Type for Various Levels of Funding

The percentage of benefits provided by rail system type for the various levels of funding is provided in Figure 1.4. This data indicates that at the 50 percent funding level, approximately 54 percent of the total benefits would be obtained by the rapid rail systems, between 13 and 29 percent by the commuter rail systems, and less than 2 percent by the light rail systems, depending upon the method used to establish benefits. At the 75 percent funding level, the rapid rail systems would receive between 60 and 67 percent of the total benefits, the commuter rail systems between 18 and 34

FIGURE 1.4

PERCENT BENEFIT BY RAIL TYPE FOR VARIOUS LEVELS OF FUNDING

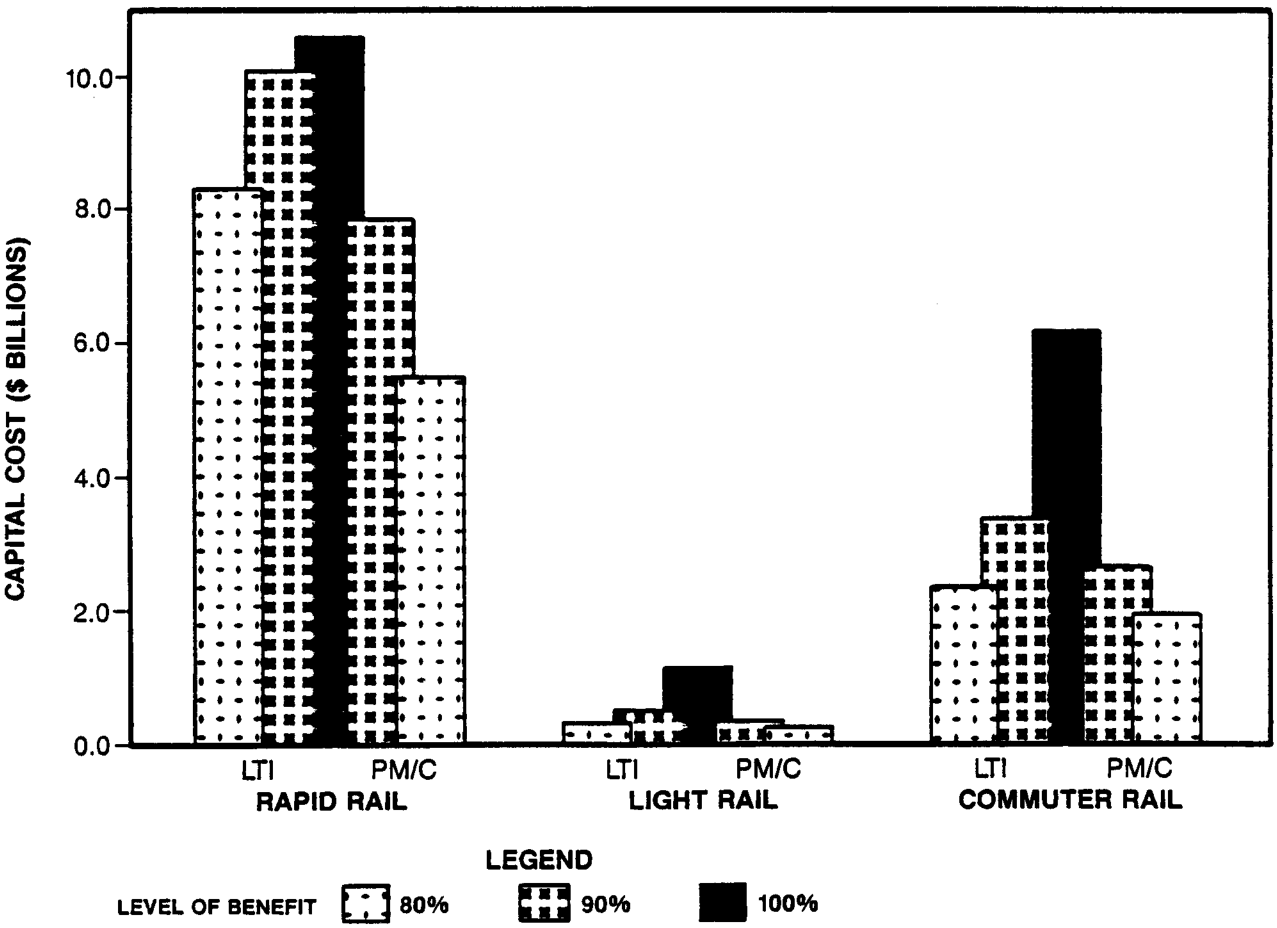


percent of the total benefits and the light rail systems about 2 percent of the benefits, depending upon the method used to establish the benefits. At the 100 percent level of funding, the rapid rail systems would receive more than 60 percent of the benefits, the commuter rail systems more than 28 percent of the benefits, and the light rail systems would receive the remainder. At the 100 percent level of funding, the differences in benefits between the two methods is related to the total magnitude of the benefits and in the difference in procedures in estimating the benefits.

o Capital Costs by Rail Type for Various Levels of Benefit

The capital costs by rail system type for various levels of benefit are provided in Figure 1.5. The information in this figure indicates that in order to achieve 80 percent of the benefits, between $5.5 and $8.3 billion would be required to modernize and rehabilitate the rapid rail systems, between $1.9 and $2.4 billion for the commuter rail systems, and more than $220 million for the light rail systems. At the 90 percent level of benefit, between $7.8 and $10.0 billion would be required to modernize and

FIGURE 1.5
CAPITAL COST BY RAIL TYPE FOR VARIOUS LEVELS OF BENEFIT

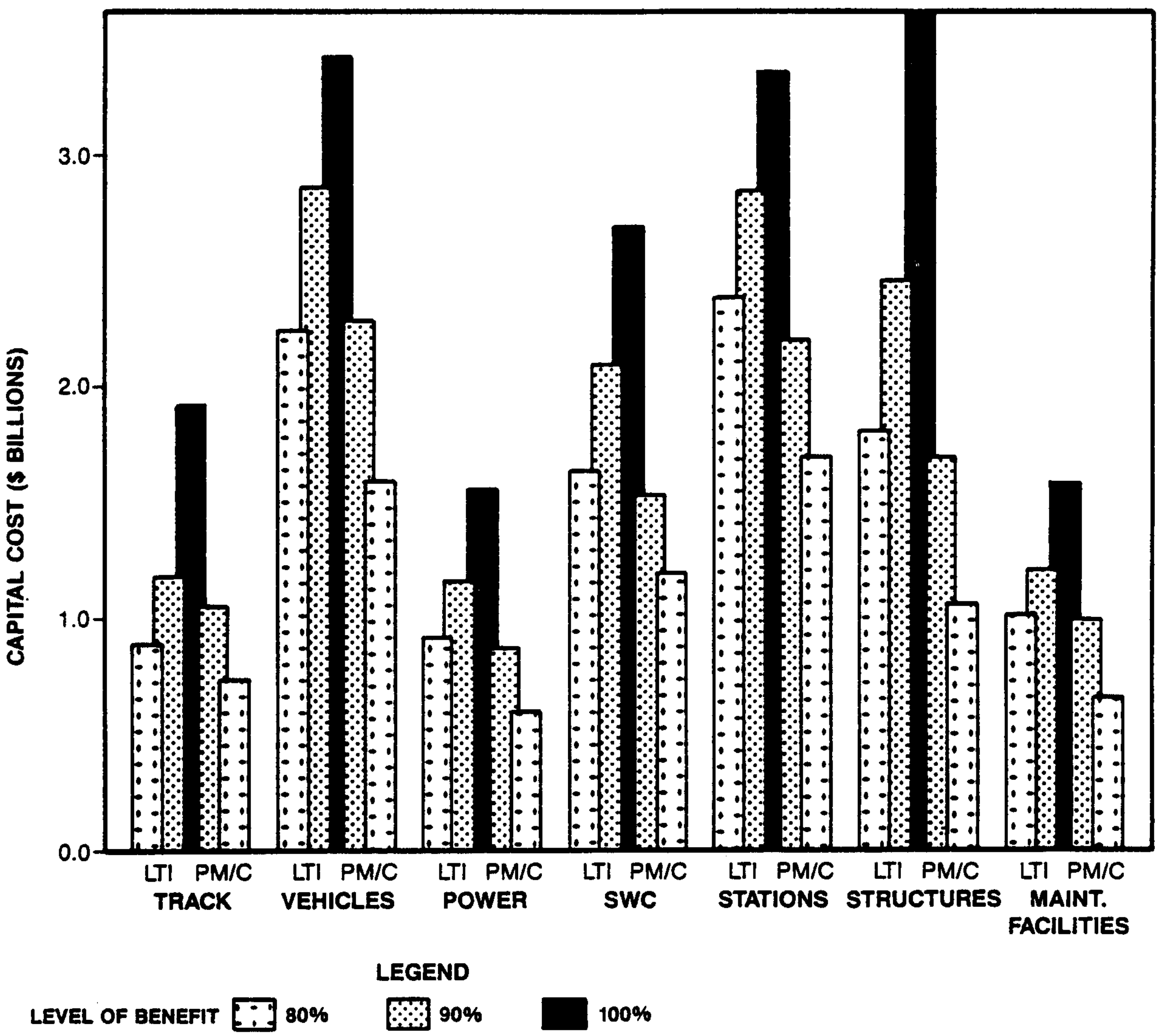


rehabilitate the rapid rail systems, between $2.6 and $3.4 billion for the commuter rail systems, and between $250 and $500 million for the light rail systems. In order to obtain 100 percent of the benefits, more than $10.6 billion would be required to modernize and rehabilitate the rapid rail systems, more than $6.2 billion to modernize and rehabilitate the commuter rail systems, and slightly more than $1.0 billion to rehabilitate the light rail systems.

o Capital Costs by System Element for Various Benefit Levels

The capital cost by system element for various benefit levels are provided in Figure 1.6. This information indicates that in order to receive 80 percent of the total benefits, between $735 and $886 million would be required for track improvements, between $1.6 and $2.25 billion for vehicle improvements, between $634 and $923 million for power distribution

FIGURE 1.6
CAPITAL COSTS BY ELEMENT FOR VARIOUS BENEFIT LEVELS



improvements, between $1.2 and $1.7 billion for system-wide control improvements, between $1.7 and $2.4 billion for station improvements, between $1.0 and $1.8 billion for structure improvements and between $682 million and $1.0 billion for maintenance facility improvements.

In order to obtain 90 percent of the benefits, between $1.0 and $1.2 billion would be required for track improvements, between $2.26 and $2.84 billion for vehicle improvements, between $875 million and $1.2 billion for power distribution improvements, between $1.5 and $2.1 billion for system-wide control improvements, between $2.2 and $2.8 billion for station improvements, between $1.7 and $2.5 billion for structure improvements, and between $1.0 and $1.2 billion for maintenance facility improvements.

- Summary of Costs for Various Funding Levels

Varying the investment in capital improvements in accordance with the measure of benefits affects the distribution of funding in a variety of ways. Analyses of improvements for each segment/branch in the priority suggested by the benefit/cost ratios results in the estimated costs shown in Table 1.7 for the different types of transit systems.

1.13 CHANGES IN CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS

The changes in condition resulting from improvements at different levels of capital expenditure are discussed in the following sections for each system element/major subsystem.

- Track

The track condition for various capital expenditure levels is illustrated in Figure 1.7. Approximately 2,800 miles of track were identified as requiring capital improvements during the 10-year period to bring all track to "good" or better condition. If none of this track is improved, then approximately 2,340 miles will remain in "fair", "poor", or "bad" condition. If all of the improvements are completed, then all of the track will either be in

TABLE 1.7

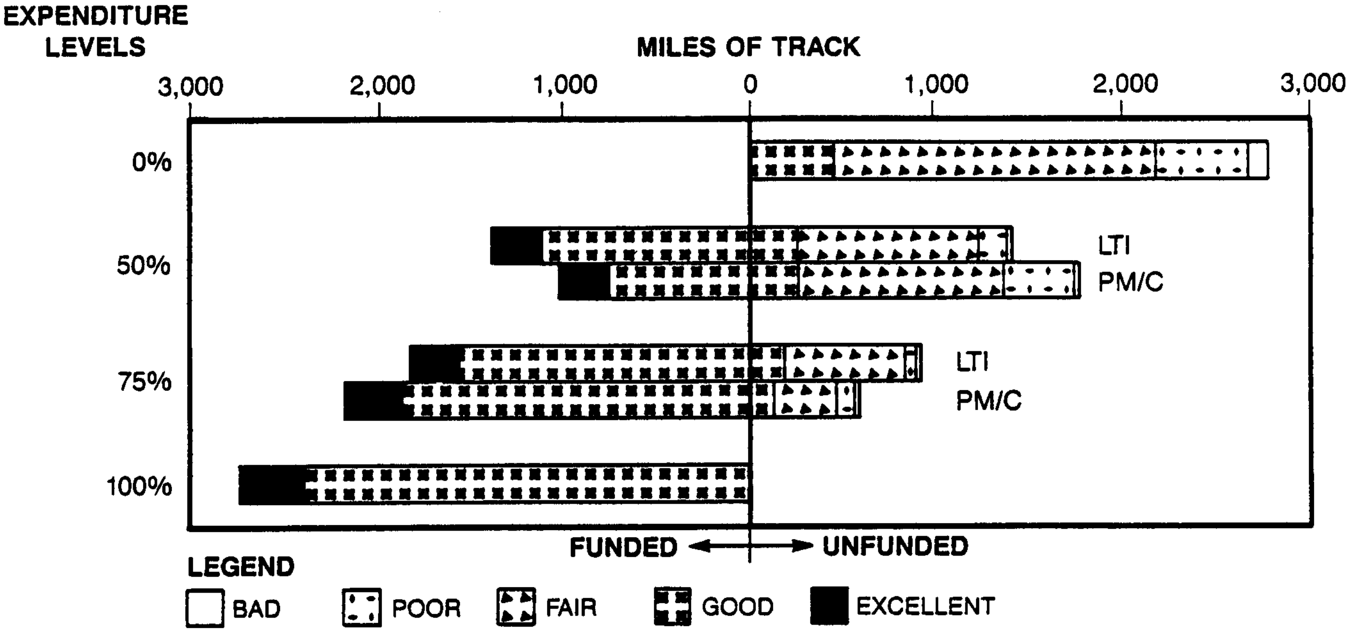
Costs for Various Funding Levels by Type of Transit System

($-Billion)

Funding Level (%)	Levels of Funding		Types of Transit Systems					
			Rapid Rail		Light Rail		Commuter Rail	
	LTI	PM/C	LTI	PM/C	LTI	PM/C	LTI	PM/C
50%	8.806	8.802	6.901	6.520	0.199	0.246	1.706	2.036
50%	10.566	10.713	7.962	7.862	0.226	0.246	2.378	2.604
75%	13.254	13.254	9.814	8.688	0.478	0.430	2.962	4.136
100%	17.876	17.876	10.620	10.620	1.052	1.052	6.204	6.204

FIGURE 1.7

TRACK CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS



"good" or "excellent" condition. If 50 percent of the proposed improvements are made, then between 1,150 and 1,540 miles of track will be in "bad" to "fair" condition. If 75 percent of the proposed improvements are made, between 480 and 765 miles of track will still be in "bad" to "fair" condition, as shown in the figure.

o Vehicles - Self-Propelled Rail Cars

The self-propelled vehicle condition for various capital expenditure levels is illustrated in Figure 1.8. Approximately 14,000 improvement actions on self-propelled vehicles were identified for the 10-year period to bring all vehicles to "good" or better condition (except where infeasible). If none of the improvements are funded, then approximately 9,500 self-propelled vehicles will be in "bad" to "fair" condition. If all of the improvements are completed, then all but 1,900 self-propelled vehicles will be in "good" or "excellent" condition. These 1,900 self-propelled vehicles are all relatively old vehicles that would be kept in "fair" condition through rehabilitation and refurbishment but are too old to be improved to a better condition. If 50 percent of the proposed improvements are made, then between 2,650 and 3,200 self-propelled vehicles would be in "bad" to "fair" condition. However, if 75 percent of the proposed improvements are made, between 625 and 1,300 self-propelled vehicles would still remain in "bad" to "fair" condition.

o Vehicles - Locomotives

The locomotive condition for various capital expenditure levels is provided in Figure 1.9. Approximately 400 improvement actions on locomotives were identified for the 10-year period to

FIGURE 1.8

SELF-PROPELLED VEHICLE CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS

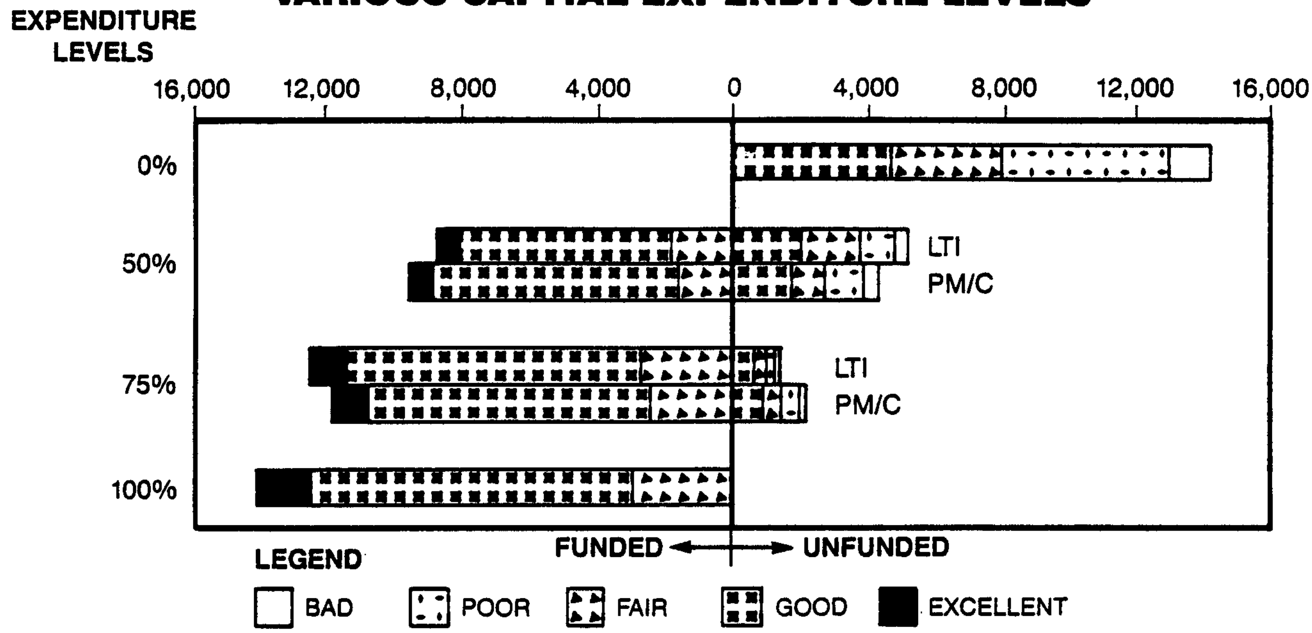
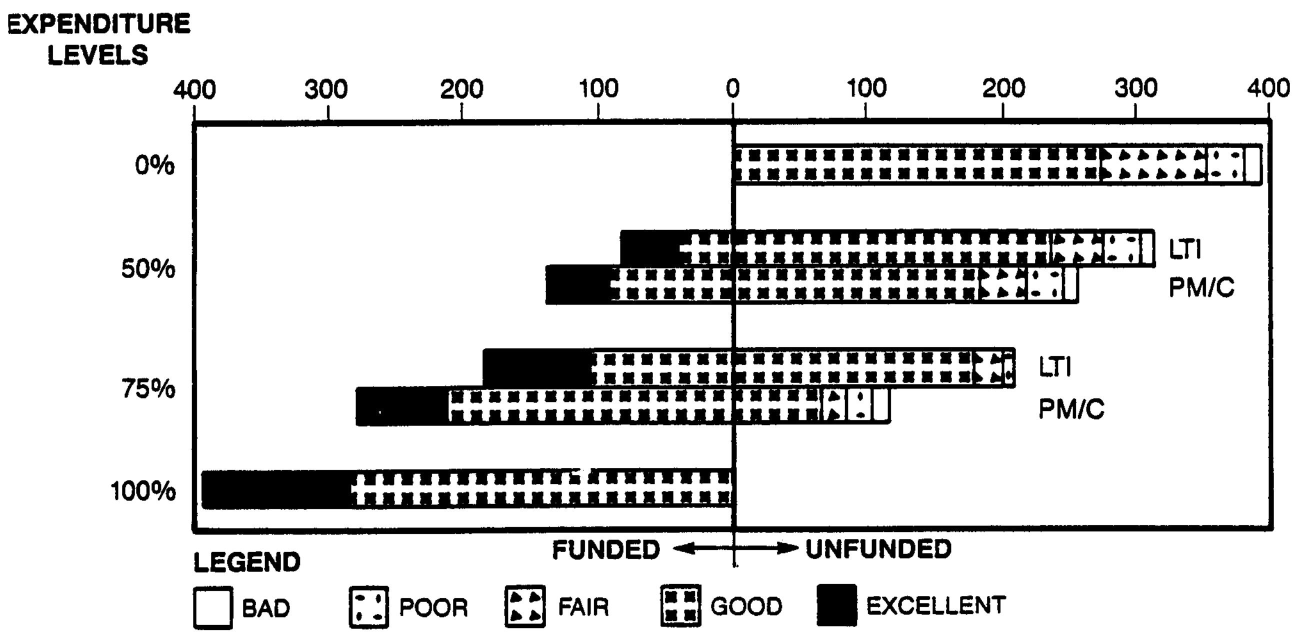


FIGURE 1.9

LOCOMOTIVE CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS



bring all locomotives to "good" condition. If none of the improvements were completed, then approximately 120 of these locomotives would be in "bad" to "fair" condition. If all of the improvements are completed, then all of the locomotives would be in either "good" or "excellent" condition. At the 50 percent level of funding, between 73 and 78 of the locomotives would be in "bad" to "fair" condition. At the 75 percent level of funding, between 25 and 50 of these locomotives would still be in "bad" to "fair" condition, as shown in the figure.

- Vehicles - Unpowered Cars

  The unpowered vehicle condition for the various capital expenditure levels is provided in Figure 1.10. Approximately 1,630 improvement actions on unpowered vehicles were identified for the 10-year period to bring all unpowered cars to "good" or better condition. If none of the improvements are made, then 350 of these unpowered vehicles would be in "poor" to "fair" condition. If all of the proposed improvements were made, then all the unpowered vehicles would be in either "good" or "excellent" condition. If 50 percent of the proposed improvements were made, between 260 and 300 of the unpowered vehicles would be in "poor" to "fair" condition. At the 75 percent level of funding, between 140 and 230 of the unpowered vehicles would be in either "poor" or "fair" condition, as shown in the figure.

- Power Distribution - Substations

  The substation condition for various capital expenditure levels is provided in Figure 1.11. Approximately 470 improvement actions on substations were identified for the 10-year period to bring all substations to "good" or

FIGURE 1.10
UNPOWERED VEHICLE CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS

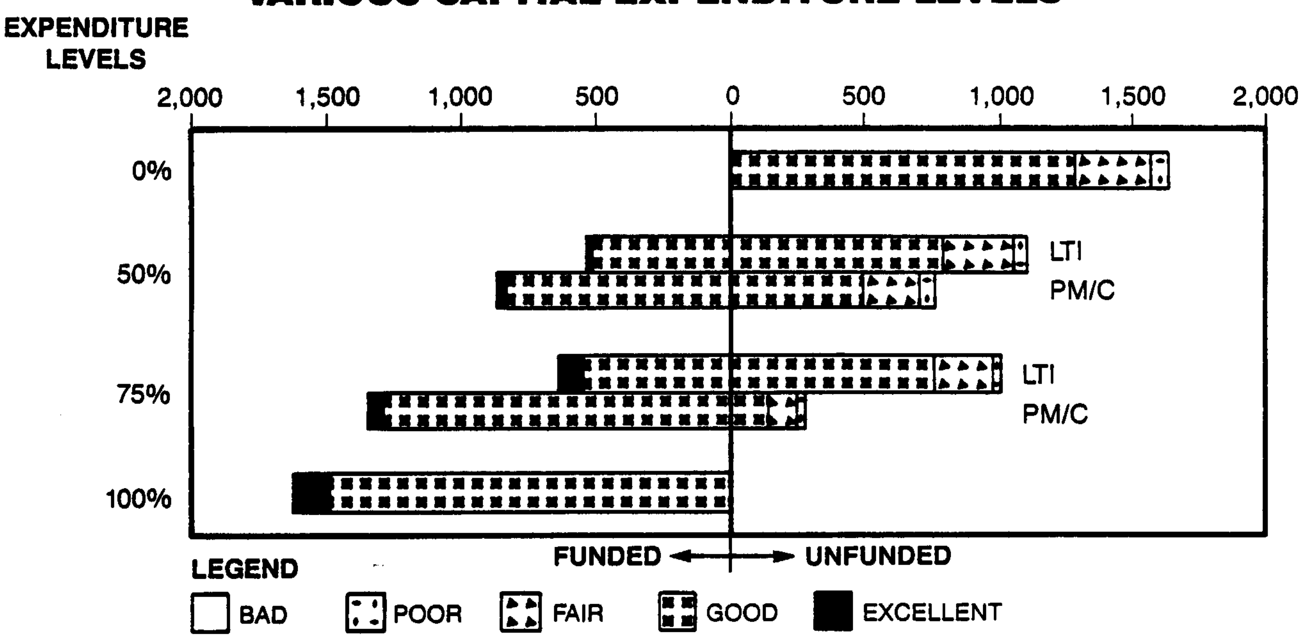
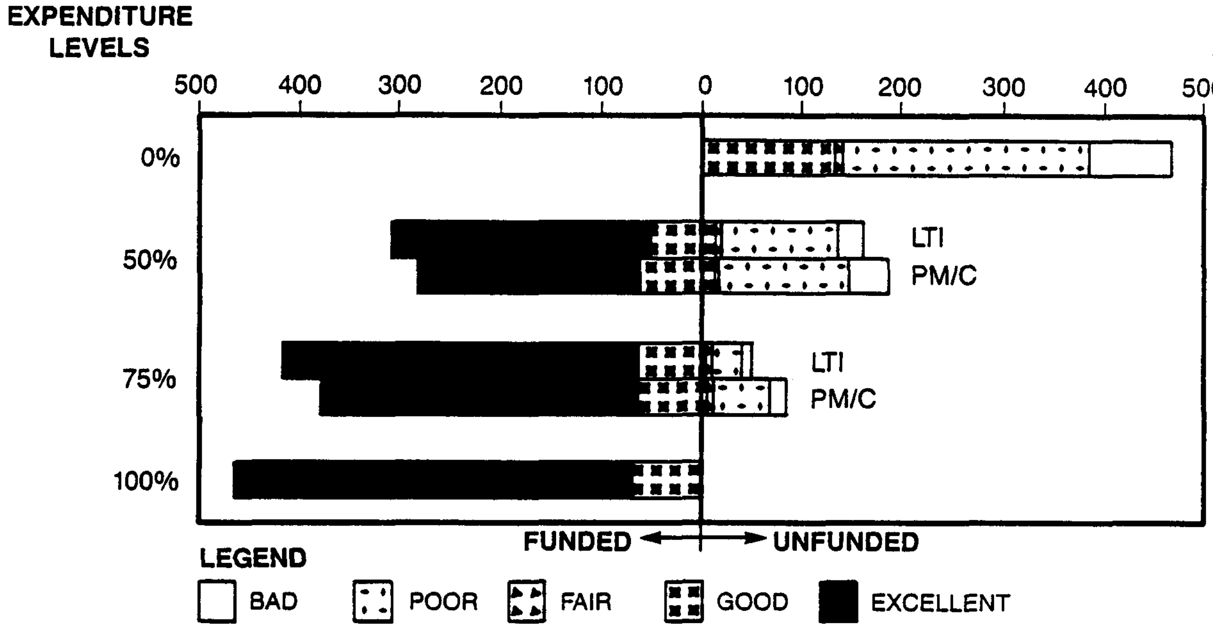


FIGURE 1.11
SUBSTATION CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS



better condition. If none of the improvements were completed, then 335 of the substations would be in "poor" to "fair" condition. If all of the proposed improvements were completed, then all of the substations would be in either "good" or "excellent" condition. At the 50 percent level of funding, between 150 and 175 of the substations would be in "bad" to "fair" condition. At the 75 percent level of funding, between 46 and 80 of the substations would be in "bad" to "fair" condition, as shown in the figure.

- o Power Distribution - Overhead Wire

The overhead wire condition for various capital expenditure levels is provided in Figure 1.12. Approximately 7.2 million feet of improvement actions on overhead wire was identified for the 10-year period to bring all overhead wire to "good" or better condition. If none of these improvements were completed, then approximately 6.5 million feet of overhead wire would remain in "bad" to "fair" condition. If all of the proposed improvements were completed, then all of the overhead wire would be in "excellent" condition. At the 50 percent level of funding, between 2.3 and 3.6 million feet of overhead wire would be in "bad" to "fair" condition. At the 75 percent level of funding, between 1.9 and 2.0 million feet would be in "bad" to "fair" condition.

- o Power Distribution - Third Rail

The third rail condition for various capital expenditure levels is provided in Figure 1.13. Approximately 4.8 million feet of improvement actions on third rail was identified for the 10-year period to bring all third rail to "good" or better condition. If none of the proposed improvements were

FIGURE 1.12
OVERHEAD WIRE CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS

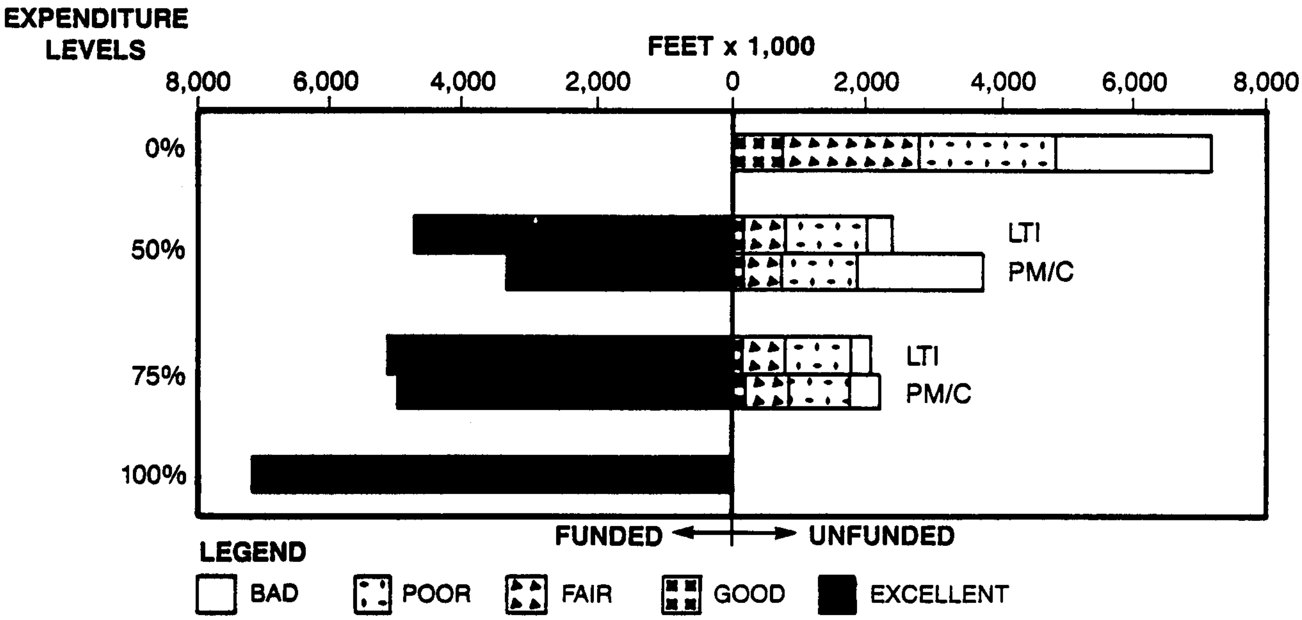
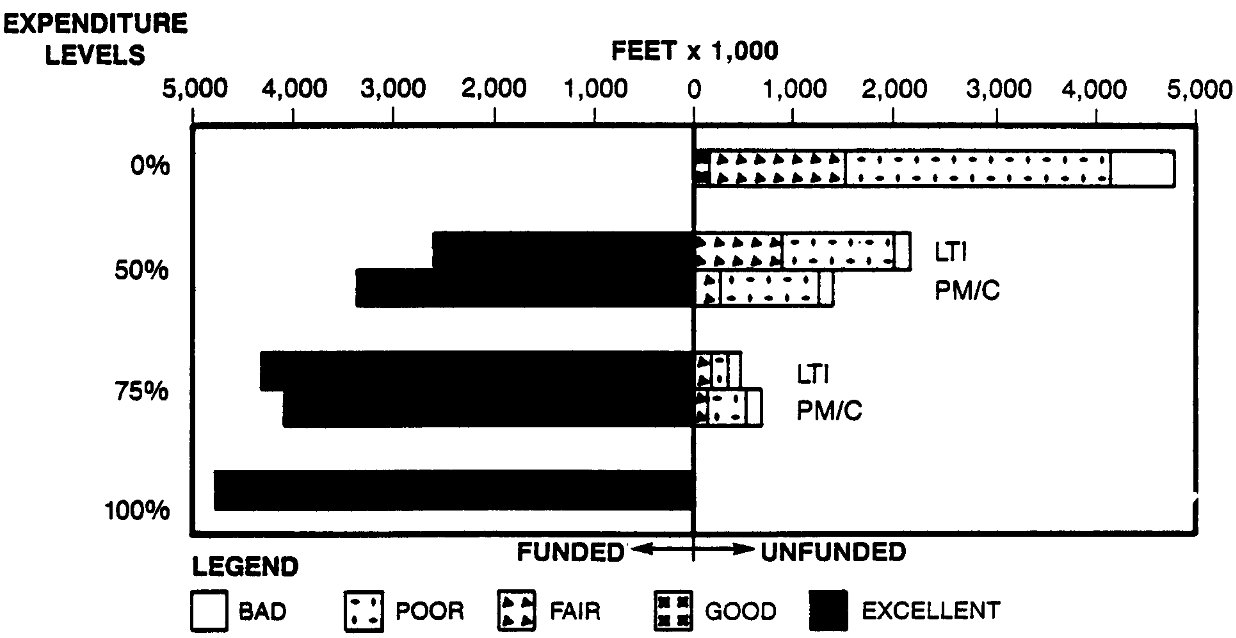


FIGURE 1.13
THIRD RAIL CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS



funded, approximately 4.6 million feet of third rail would remain in "poor" to "fair" condition. However, if all of the third rail improvements were completed, all of this third rail would be in "excellent" condition. At the 50 percent level of funding, between 1.4 and 2.2 million feet of third rail would remain in "bad" to "fair" condition. At the 75 percent level of funding, between .4 and .7 million feet of overhead wire would be in "bad" to "fair" condition, as shown in the figure.

o Stations

The station condition for various capital expenditure levels is provided in Figure 1.14. Approximately 25 million square feet of station area was identified as requiring improvements during the 10-year period to bring all stations to "good" or better condition. If all of the proposed improvements were not funded, then approximately 19 million square feet of station area would be in "bad" to "fair" condition. If all of the proposed improvements were funded, then all but 2,200 square feet of station area would be in either "good" or "excellent" condition. At the 50 percent level of funding, between 7.2 and 7.8 million square feet of station area would be in "bad" to "fair" condition. At the 75 percent level of funding, between 2.2 and 3.4 million square feet of station area would still be in "bad" to "fair" condition, as shown in the figure.

o Structures and Facilities -Bridges

The bridge condition for various capital expenditure levels is provided in Figure 1.15. Approximately 10.7 million square feet of bridge area was identified as requiring improvements during the 10-year period to bring all bridges

FIGURE 1.14
STATION CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS

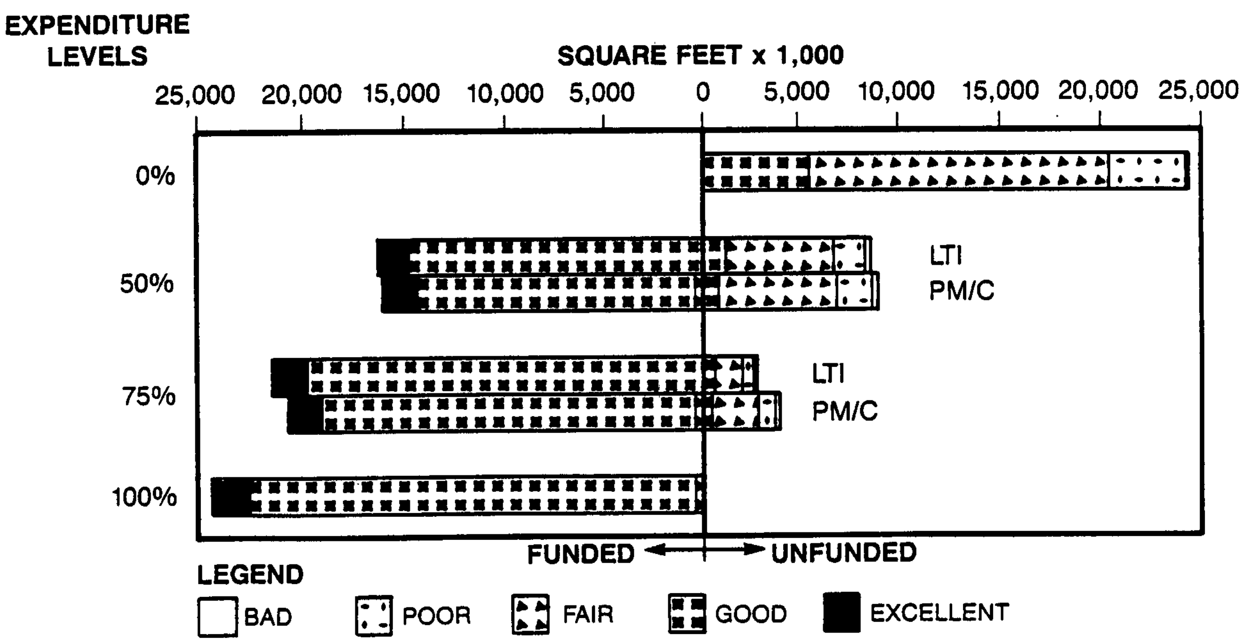
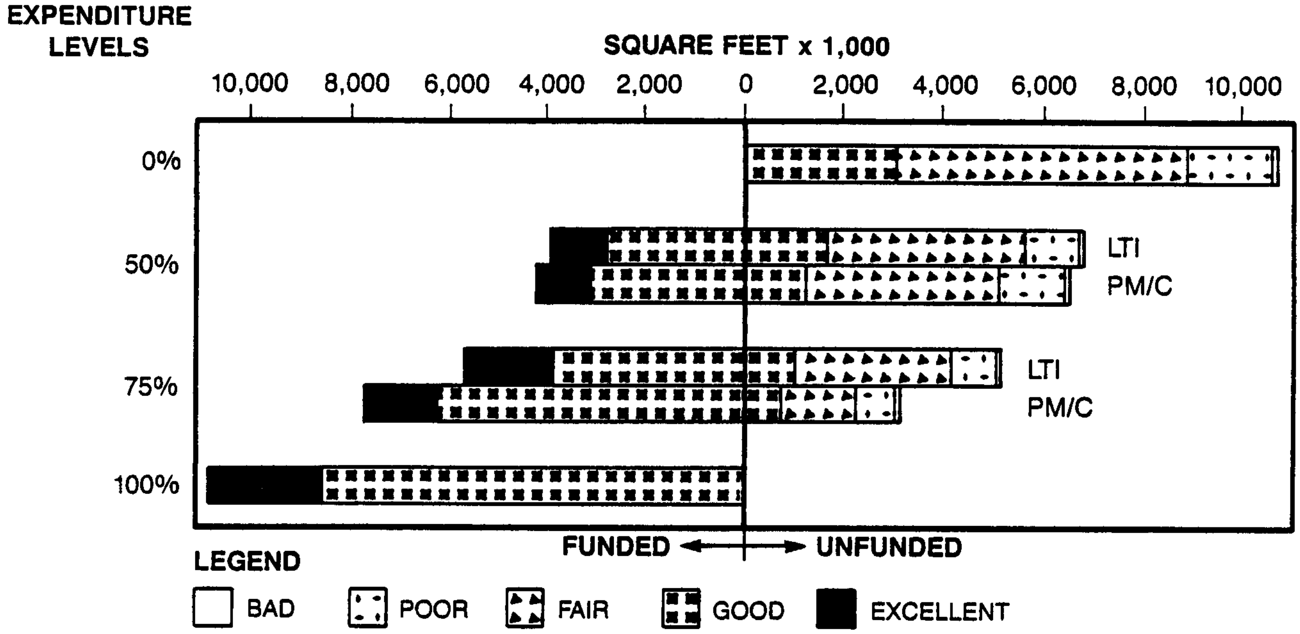


FIGURE 1.15
BRIDGE CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS



to "good" or better condition. If none of the proposed improvements were completed, approximately 7.6 million square feet of bridge area would be in "bad" to "fair" condition. However, if all of the proposed improvements were completed, all of the bridge area would be in either "good" or "excellent" condition as shown in the figure. At the 50 percent level of funding, between 5.1 and 5.2 million square feet of bridge area would be in "bad" to "fair" condition. At the 75 percent level of funding, between 2.4 and 4.2 million square feet of bridge area would be in "bad" to "fair" condition.

- o Structures and Facilities -Elevated Railways

The elevated railway condition for various capital expenditure levels is provided in Figure 1.16. Approximately 1.0 million lineal feet of elevated railway was identified as requiring improvement during the 10-year period to bring all elevated railways to "good" or better condition. If none of the proposed improvements were completed, approximately 950,000 lineal feet of elevated railways would be in "bad" to "fair" condition. However, if all of the improvements were completed, all of the elevated railway would be in "good" or "excellent" condition. At the 50 percent level of funding, between 320,000 and 400,000 lineal feet of elevated railway would be in "bad" to "fair" condition. At the 75 percent level of funding, between 98,000 and 225,000 lineal feet of elevated railway would be in "bad" to "fair" condition.

- o Structures and Facilities - Tunnels

The tunnel condition for various capital expenditure levels is provided in Figure 1.17.

FIGURE 1.16

ELEVATED RAILWAY CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS

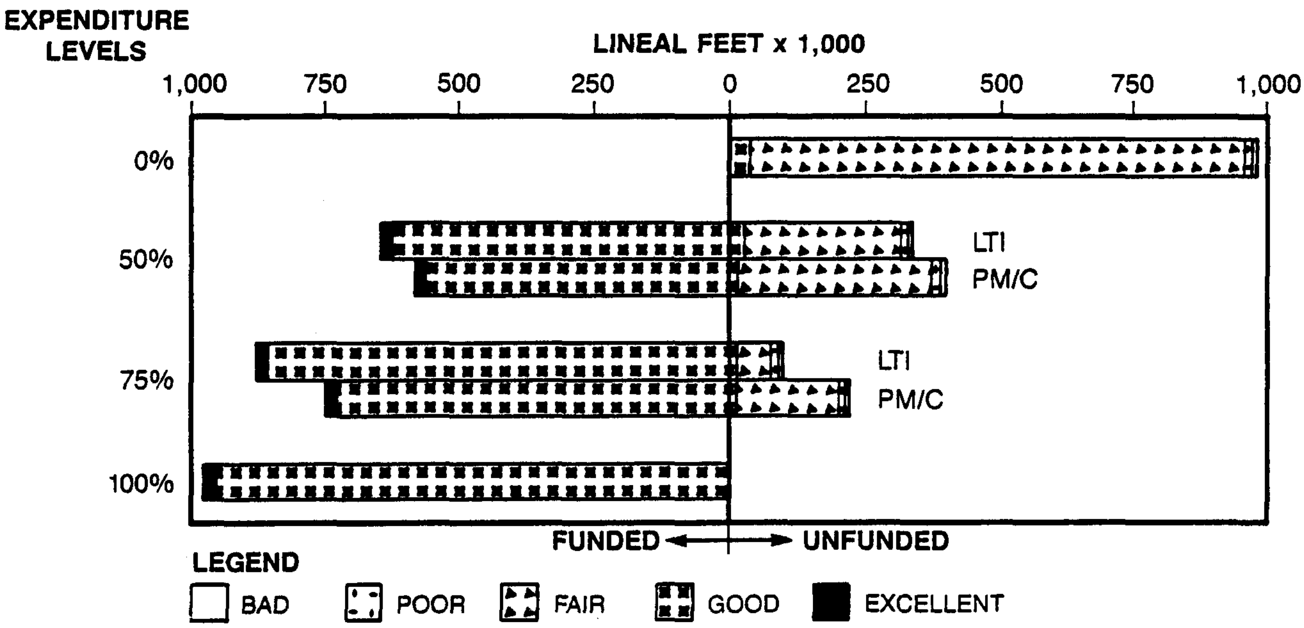
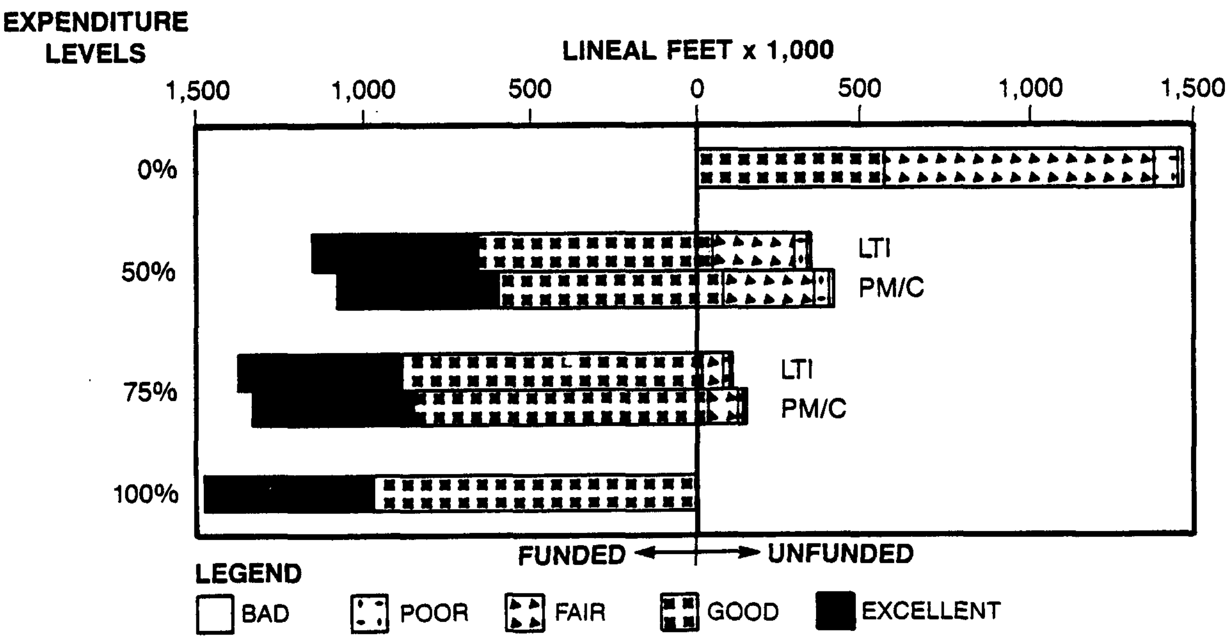


FIGURE 1.17

TUNNEL CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS



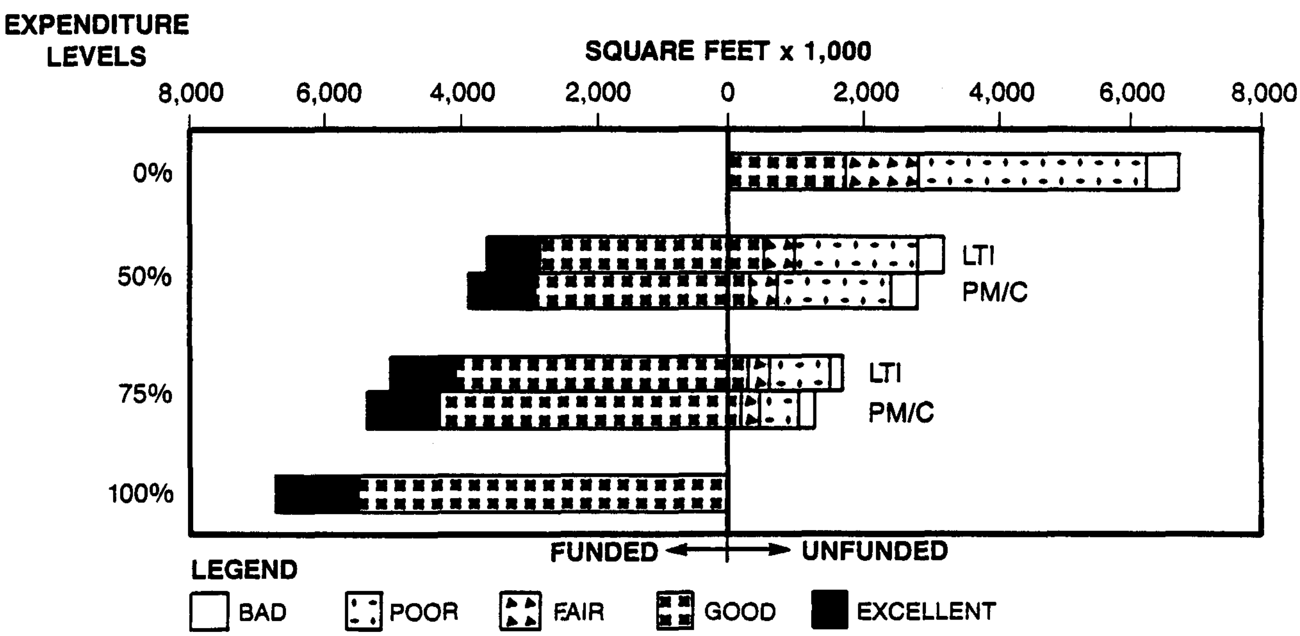
Approximately 1.5 million lineal feet of tunnel area was identified as requiring improvements during the 10-year period to bring all tunnels to "good" or better condition. If none of these proposed improvements were completed, approximately 900,000 lineal feet of tunnel would be in "bad" to "fair" condition. However, if all of the improvements were completed, all of the tunnel area would be in "good" or "excellent" condition. At the 50 percent level of funding, between 300,000 and 320,000 lineal feet of tunnel would remain in "bad" to "fair" condition. At the 75 percent level of funding, between 90,000 and 115,000 lineal feet of tunnel area would remain in "bad" to "fair" condition, as shown in the figure.

o Maintenance Facility Buildings

The maintenance facility building condition for various capital expenditure levels is provided in Figure 1.18. Approximately 6.8 million square feet of maintenance facility building area was identified as requiring improvements during the 10-year period to bring all maintenance facility buildings to "good" or better condition. If none of the improvements were completed, then more than 5.0 million square feet of maintenance facility building area would remain in "bad" to "fair" condition. However, if all of the proposed improvements were completed, then all of the maintenance facility buildings would be in either "good" or "excellent" condition. At the 50 percent level of funding, between 2.6 and 2.7 million square feet of maintenance facility building area would be in "bad" to "fair" condition. At the 75 percent level of funding, between 1.1 and 1.5 million square feet of maintenance facility building area would be in "bad" to "fair" condition.

FIGURE 1.18

MAINTENANCE FACILITY BUILDING CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS



o Maintenance Facility Yards

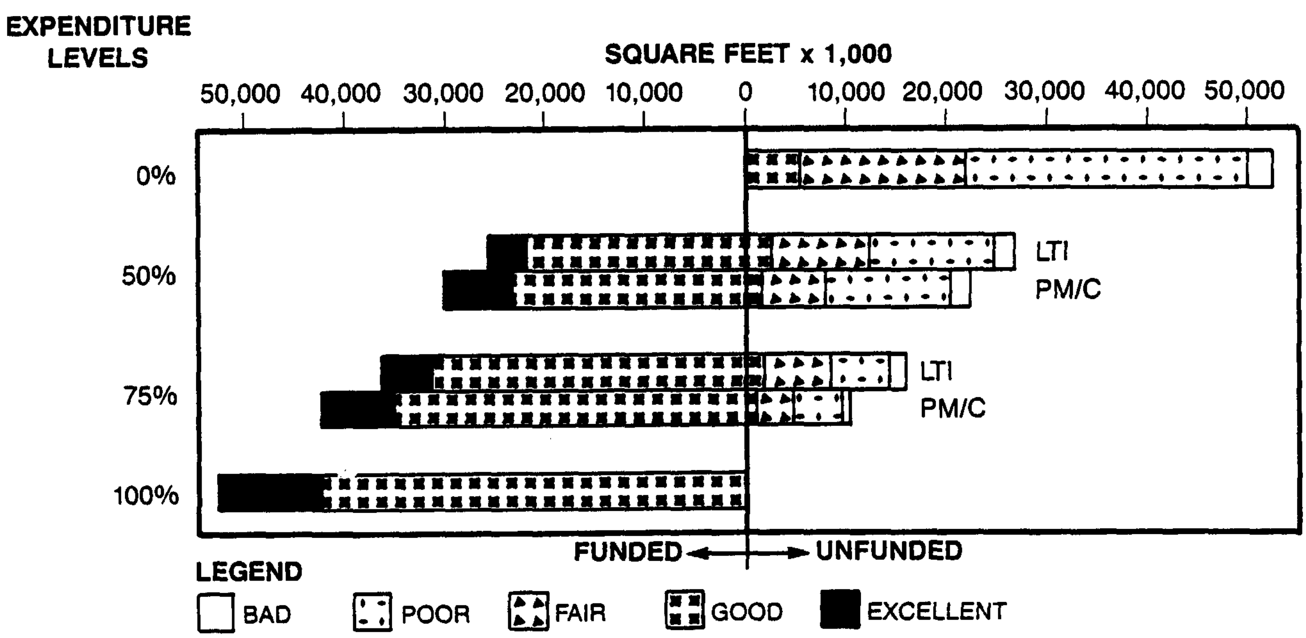
The maintenance facility yard condition for various capital expenditure levels is provided in Figure 1.19. More than 52.0 million square feet of maintenance facility yards were identified as requiring improvement during the 10-year period to bring all maintenance facility yards to "good" or better condition. If none of the proposed improvements were completed, approximately 47.0 million square feet of maintenance facility yards would be in "bad" to "fair" condition. If all of the proposed improvements were completed, all of the maintenance facility yards would be in "good" to "excellent" condition. At the 50 percent level of funding, between 21.0 and 24.0 million square feet of maintenance facility yard area would be in "bad" to "fair" condition. At the 75 percent level of funding, between 10.0 and 14.0 million square feet of maintenance facility yard area would be in "bad" to "fair" condition, as shown in the figure.

1.14 SOURCES OF LOCAL FINANCING FOR RAIL MODERNIZATION

The study investigated twelve major metropolitan areas served by rail transit systems, and analyzed current funding scenarios and potential future sources of local funding for operating and capital expenditures by these rail systems. The rail systems, all publicly owned and operated, included the older established systems such as MTA in New York, SEPTA in Philadelphia and CTA in Chicago, as well as the newer systems such as Washington's WMATA and San Francisco's BART. The systems range in size from San Diego's MTDB with an operating and capital budget of $7.6 and $17.2 million (1986), respectively, to MTA with $4.1 and $1.5 billion for annual operating and capital expenditures (1986).

The sources of funds to maintain and operate the transit systems come from

FIGURE 1.19
MAINTENANCE FACILITY YARD CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS



several sources. Direct transit system revenues (in most cases almost entirely from the fare-box) support portions of the system operating costs, ranging from a low of 22 percent in Pittsburgh's PAAC to a high of 75 percent for the Philadelphia-Southern New Jersey PATCO. The highest fare-box "recovery ratio" for systems other than those operated and supported by major Authorities with other sources of income (PATH and PATCO) is achieved by San Diego's MTDB at 72 percent.

The remainder of the operating costs (operating deficit) and all of the costs associated with capital improvements are provided from other sources, usually local, state and federal governments. Most of the systems rely on the federal government for both operating and capital assistance; notable exceptions are the two fairly new western systems, BART and MTDB, which receive no federal operating support, and PATCO. In terms of capital funding, all of the systems except PATH utilize federal funds, primarily from the UMTA Section 3 and 9 programs, but also from Interstate Transfer.

State funds for operating deficits are utilized by all the non-Port Authority supported systems, except MARTA, which is prevented from receiving such funds through the enabling legislation that established a local sales tax increment for transit support. State funds for capital improvements are used by all systems, again with the exception of PATH.

Local funds, from city and from county governments or from dedicated local taxes, are used by all of the systems except MTDB (which uses no local funds for either operating or capital purposes) and MBTA which uses local funds for operating support but not for capital programs.

In all of the transit systems, there is a desire to secure long-term, reliable funding; some of the systems—most notably BART and MARTA—have dedicated taxes flowing to the systems. At the other end of the spectrum is the New Jersey Transit Corporation which has to rely on annual budget allocations in the New Jersey DOT budget, where transit has to compete with other priorities on a yearly basis. It is clear that those cities with limited funding will have to be more creative in the future in capturing the benefits of transit through mechanisms such as benefit assessment districts and joint development.

Joint development is real estate development that is closely linked to public transportation services and station facilities. It relies on the market and locational advantages provided by transit to enhance the value of the development. Joint development provides financial support for transit agencies indirectly by increasing fare-box revenues and directly through developer contributions and lease or other payments. Joint development has been successfully employed in old systems, such as Boston, New York and Philadelphia and in new systems such as Atlanta and Washington. In New York, developers have made major improvements in stations in return for higher density zoning. One developer has made a $25.6 million contribution to rebuilding a subway station. Two others are making improvements valued at $5 million or more each. WMATA estimates it will receive $3.5 million this year in joint development income. This represents the annual receipts for leases and other payments.

Joint development has only recently emerged as an important potential revenue source for transit systems. Successful implementation requires cooperation from local governments and developers as well as active support by the transit agency. The potential for increased revenues from joint development is considerable and should receive greater attention in the future.

1.15 CONCLUSIONS

This study has assessed the current condition of the rail transit systems, developed a series of improvements designed to return all elements and subelements of the systems to "good" condition, assessed the cost-effectiveness of these proposed improvements and identified a wide range of new sources of funding for rail modernization improvements. The study found that the condition of the rail systems varied widely by subelement with maintenance facilities, yards and self-propelled rail cars in the worst condition, and substations, unpowered cars, locomotives and tunnels in the best condition. The actions needed to restore the elements and subelements included no action where elements would remain in "good" condition and ranged from refurbishment (most of the unpowered cars and many of the stations and tunnels), through rehabilitation (most of the elevated railway, bridges and structures and locomotives) to modernization (most of the power systems, maintenance facilities and yards and system-wide controls).

The assessment of cost effectiveness indicated that there was a wide variation on the segments studied. On the basis of net social benefits, the "best" segment comes out 35 times better than the "worst". These findings support a conclusion that it would be impractical, and a misuse of resources, to upgrade a number of low utilization rail lines which produce few benefits for the investments proposed. However, those segments that are not proposed for improvement should be analyzed to determine the most cost effective way to provide necessary transportation services.

The wide range of cost effectiveness is further illustrated by the fact that, when ranked on the basis of their cost effectiveness, segments of the rail transit systems serving 84 percent of the total number of passenger miles on the systems can be restored to "good" condition at a cost of $8.8 billion (in 1983 dollars), only half of the cost of restoring all segments. Similarly, 69 percent of the net social benefits obtained from restoring all segments can be achieved at the same cost. The total cost to restore all segments is $17.8 billion.

These factors indicate the need for further analysis of those projects which are least cost-effective. This would be true no matter what the source of funds for these projects: federal, state, local or private. If the funds are not targeted, there is the danger that they will be misused on improvements to marginal lines with little ridership and the higher utilized segments of the systems may remain in unsatisfactory condition. State and local decisionmakers will have to make the difficult choices necessary to prevent this from happening. As funding shifts more and more to this level of government, such choices are likely to become even more important.

2.0 INTRODUCTION

This section of the report establishes the framework for the study that determined the current condition of selected transit systems, proposed improvements and associated costs. This framework provides a systematic, comprehensive, and consistent basis for rail modernization, rehabilitation, and refurbishment decisions, and associated strategies. The premises, assumptions and procedures were established prior to the inspection of any of the transit systems, since they involved the development of a comprehensive schedule for the physical inspection and evaluation of the transit systems. It was also necessary to obtain agreement on assumptions, descriptions, definitions, and decision rules that were used throughout the conduct of the study.

To provide technical support and a mechanism to include the individual rail transit operators in the decision-making process of the study, a Rail Modernization Study Liaison Board (RMSLB) was established through the American Public Transit Association (APTA). This board's chief tasks were to provide technical guidance and industry viewpoint; provide comments and recommendations on the framework, definitions and goals of the study effort; review and comment on interim reports and the draft final report and; obtain, consolidate, and submit comments of the rail transit operators, during the process of the study, to UMTA.

Within this framework, the following factors are addressed:

- o The background of the study.
- o The definitions of different types of transit systems; modernization, rehabilitation, and refurbishment; system elements; condition codes, and levels of improvement.
- o The general procedure used in defining rail modernization requirements.
- o The general concepts for developing the basic cost estimates.

2.1 BACKGROUND

At the request of Congress, UMTA has conducted a study designed to develop and analyze the costs required to restore all urban rail transportation systems to a level that is consistent with current standards of safety, reliability, and aesthetics for new rail systems. That is, upon completion of the proposed improvements, these transit systems would be at a level that would counteract whatever neglect and deterioration had set in over the past quarter century or more because of extensive deferred maintenance. The congressional mandate spoke of a 10-year investment effort at the end of which relatively modest annual maintenance expenditures would retain the rail systems in a "good" operating condition.

The work involved two phases; the engineering cost estimate of the many repair actions needed to perform such an upgrade, plus an initial cost benefit assessment of how worthwhile these various projects are relative to each other, and relative to the objective investment criteria to be developed by the study.

The results of the Engineering Cost Estimate Phase of this study include:

- o A discussion of modernization/rehabilitation/refurbishment goals and objectives.
- o Descriptions of the types of transit systems, system elements and subelements evaluated.
- o Definitions of the conditions and level of proposed improvements.
- o Procedures for identifying repair and replacement actions.
- o The general concepts for developing the basic cost estimates to fully restore the rail transit systems to meet the most desirable operating conditions.

Thirty-four rapid, light and commuter rail systems were inspected and evaluated for possible modernization and rehabilitation during the 10-year period from 1985 to 1994. The current condition of each system element (i.e., track, vehicles, power distribution, signal and communication systems, stations, structures and maintenance facilities) of each transit system was determined, improvement actions were proposed, and capital costs estimated. The engineering cost estimate phase focused on the total improvement and cost of upgrading and modernizing rail transit to be consistent with the current standards of safety, reliability, efficiency and aesthetics.

The Rail Modernization Study Cost-Effectiveness Phase focused on amplifying the engineering cost estimates already obtained with ridership estimates to assess the cost effectiveness of the improvements identified and to develop a priority-ordered final product based on alternative scenarios of available funding. Various cost effectiveness prioritization concepts were developed and evaluated, the transit systems were divided into operational and identifiable segments, the transit system utilization was estimated on each of the segments and transit system benefits and capital costs were determined for each of these system segments. An assessment of the benefits and capital costs for various capital expenditure levels was then conducted and the system element condition for various capital expenditure levels was determined.

In addition, an analysis of each rail area's ability to fund the necessary rail modernization improvements was conducted including a review of existing revenue sources and potential revenue sources, as well as the area's history of rail modernization funding.

The final evaluation includes an assessment of benefits, in terms of the change in condition and segment utilization of the proposed improvements at varying levels of expenditure. This analysis also provides some insight into the condition of the various system elements at various levels of expenditure.

2.2 STUDY SCOPE

For the purpose of this study a distinction is made between improvements to rail transit systems, subsystems or components brought about by capital investment, in contrast to such management actions as operating procedures, maintenance practices, service levels or personnel actions which also affect how a transit system functions.

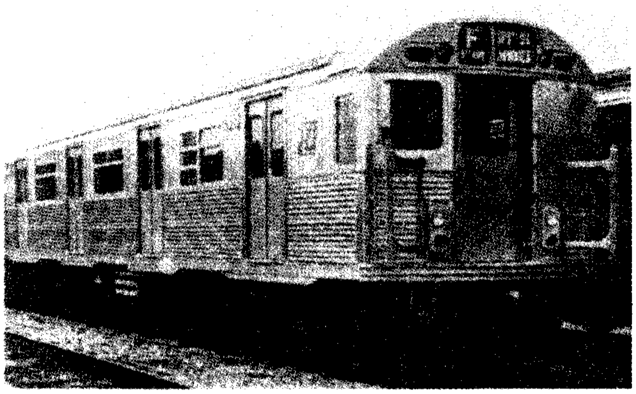
The scope of this study is limited to improvements which can be derived from capital investment. It is important to note, however, that capital improvements developed during this study are not necessarily eligible as capital expenses under current provisions of the federal urban mass transportation grant program, nor is there a presumption that such eligible costs must be covered by federal funds.

This study also focuses on upgrading and modernizing existing rail transit vehicles, structures and facilities. It is not the scope of this study to evaluate and make recommendations beyond the status quo. The study will not, in other words, include rail car fleet expansion based on future ridership projections; relocation of maintenance facilities for operational reasons; closing or combining stations due to patronage changes; or, even, abandoning outright under-utilized rail lines. Furthermore, the extension of electrification on commuter rail lines which currently operate both electric and diesel-powered trains, as well as the deployment of electrification on routes where it does not now exist, are also beyond the scope of the study. In a few instances, however, where projects to upgrade a commuter rail line are already underway and include the extension of electrification, such work has been incorporated in the study.

2.3 DEFINITIONS

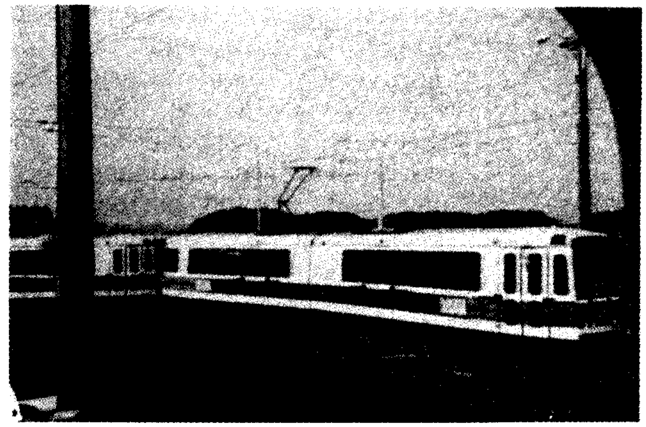
- Types of transit systems. As used in this study, rail systems are defined and divided as follows:

- Rapid Rail, sometimes known as "subway" or "elevated", operates on exclusive right-of-way that may be subway, elevated, or grade separated at or near ground level. Rapid rail has electrically propelled rail cars operated in trains. Power collection is generally from a third rail. Rapid rail typically features off-vehicle fare collection and has high level platform stations.



Rapid Rail Vehicle

- Light Rail utilizes predominantly reserved, but not necessarily grade separated, rights-of-way. Electrically propelled rail cars operate singly or in trains. Light rail transit typically features on-board fare collection, overhead wire power collection, and low level platforms.
- Commuter Rail includes those "mainline railroad" operations that encompass urban passenger train service for local short distance travel between a central city and adjacent suburbs. Suburban rail passenger service using both locomotive hauled and self-propelled rail cars is characterized by multiple trip tickets, specific station-to-station or zone-to-zone fares,



Light Rail Vehicle

railroad employment practices and usually only one or two stations in the central business district.

Commuter Rail Vehicle

o Modernization, Rehabilitation, and Refurbishment.
   - Modernization is a category of rail system improvement whereby original equipment or materials are replaced with proven new equipment or materials to achieve higher levels of performance or productivity. Modernization includes the replacement of facilities and equipment which are functionally or economically obsolete with new components, subsystems, and/or entire units.

- Rehabilitation is a lesser category of rail system improvement than modernization whereby worn or weakened materials, components and subsystems are replaced with new parts having basically the same design or function as the original equipment. Rehabilitation includes the renovation of existing facilities or equipment, as necessary, to achieve original levels of service, safety, capacity or reliability.
- Refurbishment is a still lesser category of rail system improvement whereby existing equipment or facilities are restored to adequate levels of performance without the necessity for major replacement of parts or components. Refurbishment should result in the capacity to sustain existing system performance.

o System Elements. The definitions of the various system elements used in this study are as follows:
- Track; rails and other supporting features that are necessary to carry cars and locomotives. This system element includes rail, rail joints, rail fastening and anchor systems, ties or crossties, ballast, subballast, filter fabrics, special trackwork and machinery, and grade crossing subsystems.
- Vehicle; cars for carrying passengers (self-propelled or unpowered) and locomotives for pulling unpowered cars in a train. The major subsystems include vehicle structures, traction power system, electrical/electronic packages, and miscellaneous car equipment.
- Power distribution; equipment and insulations necessary to take electrical power from a primary source and distribute it along the rights-of-way for use by trains, stations, yards, shops and ancillary facilities. Major subsystems include traction power substations, overhead wire, third rail, poles, pole foundations, ducting, underground wiring, impedance bonds, and AC power substations and distribution system.

Overhead Catenary

- System-wide control; signals, cabling, relays, and related equipment necessary to provide control, communications, and various supervisory functions for a transit system. Major subsystems include the train control subsystem which provides the signals for movement of the trains. It is divided into three major components: train operations, train protection, and train supervision. The communications subsystem provides a combination of components that are necessary to provide audio/visual communications and data links between central control, vehicles, stations, shops, and the wayside. The supervisory and control subsystem includes the equipment for receiving, processing and displaying data on the operations of the system.

- Stations; the interface between a transit system and the public. In addition to system entrance and exit functions, stations provide passenger amenities and belong to a larger urban context. As such, it is important to recognize the aesthetic obligations which transcend operational transit system requirements. The several types of transit stations include historic stations, subway stations, elevated stations, at-grade stations, and light rail vehicle stops. Major subsystems include such facilities as necessary to provide horizontal circulation (passageways), vertical circulation (stairs, elevators) car boarding and deboarding (platforms), fare collection, information and security.
- Structures and facilities; bridges, tunnels, retaining walls and other supporting structures along a right-of-way to carry tracks for the passenger transit equipment. This element includes buildings and facilities as required for pumps, ventilation systems, fans, electrical substations and other ancillary equipment. Major structures and facilities include the different types of railway bridges, rapid transit bridges, highway bridges, buildings, sidings, pedestrian overpasses and underpasses, railway and rapid transit tunnels, and retaining structures.
- Maintenance facilities; buildings, shops, trackage and miscellaneous equipment necessary for maintenance, repair, servicing or storage of other elements of the transit system. The major subsystems include buildings to house maintenance and repair personnel and equipment, yard tracks and signal tower, and various types of shop equipment.

o Condition Codes and Levels of Improvement

To standardize inspection results, procedures were established which governed two aspects of the field inspections.

- Condition codes were assigned to each system element and sections or parts of system elements during the physical assessment. These condition codes are illustrated in Table 2.1 and the general definitions for each code are as illustrated. The conditions range from bad to excellent. A "bad" category was assigned to a system element that was in sufficiently poor condition, that its continued use presents potential problems. An "excellent" category was assigned to a brand new system or system element where no major problems exist and only routine preventive maintenance is required to maintain the system element in its existing condition. These general definitions were then amplified significantly by the individual inspection team leaders in order to provide more detailed definitions that could be used during the inspection of the specific transit system element and associated subsystems.
- Criteria were also developed for conducting the on-site inspections. Each team leader was responsible for developing inspection forms to record observations during the inspection. These forms

Table 2.1
CONDITION CODES

CONDITION CODE	CATEGORY	GENERAL DEFINITION
1	Bad	In sufficiently poor condition that continued use presents potential problems.
2	Poor	Requires frequent major repairs (less than 6 months between major repairs).
3	Fair	Requires frequent minor repairs (less than 6 months between repairs) or infrequent major repairs (more than 6 months between major repairs).
4	Good	Elements are in good working order, requiring only nominal or infrequent minor repairs (greater than 6 months between minor repairs).
5	Excellent	Brand new, no major problems exist, only routine preventive maintenance.

required the notation of specific defects and observed conditions. Sketches were used to illustrate the basic dimensions, the type of materials used, and the location of serious defects in the element inspected. Photographs were taken to provide a record of general observed conditions as well as for identification of specific problem areas. These photographs, along with written commentary were incorporated in memorandum reports on the condition of each transit system.

The condition coding and memorandum report provided the basis for this report.

After establishing the five condition codes and the three categories of improvement, seven levels of improvement were assigned to the current conditions as illustrated in Table 2.2. It was assumed that if the present condition of the system element or subsystem was considered to be "bad", then a major modernization effort would be required to modernize or rehabilitate this subsystem to the standards necessary. This was defined as a level 1 modernization, which meant that the system element would be replaced to meet higher standards of productivity than available with the original system element or subsystem. If the present condition was considered to be "poor", it was

Table 2.2

LEVEL OF IMPROVEMENT

Current Condition	Modernization	Rehabilitation	Refurbishment
1 **Bad** System Failed/ Non-Operational	**Level 1.** Replace system element or subsystem to meet higher standards of productivity.		
2 **Poor** Frequent Major Repairs	**Level 2.** Replace subsystem or component to meet higher standards of productivity.	**Level 3.** Replace subsystems, components or equipment with highest failure rates.	
3 **Fair** Frequent Minor Repairs	**Level 4.** Replace components or equipments with highest failure rates with new components that have higher standards of productivity than original equipment.	**Level 5.** Substitute new components for components with highest failure rates. New components should have basically the same physical dimensions and functions as original equipment.	**Level 6.** Replace components or equipment with highest failure rates with equipment that will meet adequate standards of performance.
4 **Good** Infrequent Minor Repairs			**Level 7.** Substitute components and equipments to achieve levels of safety and reliability that were intended in the original design.
5 **Excellent** Essentially New			

assumed that there could be two different levels of improvement; level 2 and level 3. The difference between these two levels of improvement is that with level 2 the subsystem or component would be replaced to meet higher standards of productivity. However, with a level 3 rehabilitation, the subsystems, components or equipment would be replaced and the new eq''ipment would at least achieve original levels of service, safety, capacity and reliability. If the condition of the system element or subsystem was "fair", then it was assumed there could be three different levels of improvement. These different options were evaluated by using various decision rules in order to establish which level of improvement was pertinent for the particular subsystem or equipment being modernized, rehabilitated, or refurbished. If the present condition of the system element or subsystem was considered to be "good", then the level of improvement was assumed to be a level 7 refurbishment, which means that the components and equipments could be substituted to achieve the levels of safety and reliability that were intended in the original design.

2.4 PROCEDURES FOR IDENTIFYING RAIL MODERNIZATION REQUIREMENTS

The procedure for identifying rail modernization projects begins with the development of decision rules to establish the types of improvements that should be included in this program and the collection of performance data to assist in further defining improvement projects.

- Decision Rules

  Decisions must be made to modernize, rehabilitate, or refurbish some of the elements, subsystems, or components of the system. Such decisions require a clear understanding of the benefits and costs of proposed improvements. The following decision rules and criteria were used in determining required improvement actions:

  - A decision as to which alternative improvement to select should reflect the general considerations that are applicable to any system element or subsystem, including the age of the element, the condition of the element, the continued life expectancy of the element, and the ability of the element to furnish the required level of transit service. Some of the more important questions involved in the decision as to which alternative improvement to select include whether or not the system element is obsolete; whether refurbishment of the element is possible, practical, and economical; whether rehabilitation of the element is possible, practical, and economical; and what impact the decision has on safety for the system, for the riding public, for the employees, and for the general public.
  - Subsystem or component replacement may be included as a part of the modernization, rehabilitation, or refurbishment decision. Several different types of replacement were envisioned including "entire" versus "partial", "in-kind" versus "in-function", "to attain prior condition" versus "to attain some improved condition", or other types of replacement.
  - Several types of existing conditions may mandate improvement actions, such as deterioration which, if not corrected, could cause safety hazards or serious disruption of service, or the unavailability of repair parts of the subsystem or component to be repaired.
  - Various judgments must also be made that are applicable to any decision to modernize, rehabilitate, or refurbish. The following illustrate such types of judgments:
    - Are in-house skills available or are contractors or jobbers available to perform the refurbishment?
    - Can adequate specifications be written to cover contracted refurbishment?
    - Is enough equipment available to continue operations while some units are not available during refurbishment? If extra units are not available, can the equipment continue to function adequately until replacements are available?
  - A listing of special judgments that are applicable to vehicles, structures, facilities, power, control, and communications include whether or not replacement "work around" procedures permit continued operations and whether or not refurbishment of facilities and structures can be accomplished without hazard to patrons and operating personnel.

A decision to replace may assume the requirement to consider a new rationale and an additional set of criteria. Replacements may involve new equipment, new technology, or they may incorporate required operational improvements.

For the purpose of this discussion, the following definitions apply:

- New Equipment. A new piece of equipment which replaces a worn, possibly obsolete piece of equipment. The replacement equipment may replace a like item or it may be a new item which performs the same function as the item being replaced yet possesses different physical characteristics.
- Technological Improvements. New equipment incorporating technological advances. This equipment should fit in one of the following categories:
  - Equipment that has been proven in transit applications, but not necessarily at the transit system considering its application (e.g., solid state electronics for signal and control systems).
  - Equipment that has been satisfactorily demonstrated in transit applications and is deemed ready for revenue applications (e.g., noise abatement, precast concrete tunnel liners, composite aluminum steel clad third rails).
  - Equipment that has been proven in other industrial applications, but not necessarily in the transit industry (e.g., liquid crystal displays, fiber optics data transmission).
- Operational Improvement. A new operational procedure, perhaps using a new piece of equipment, for the purpose of improving service or eliminating a defect (e.g., crossovers to facilitate failure management, integrated couplers to facilitate making up train consists). Though such procedures and related equipment may not have been tried at the transit system where use is contemplated, they should have been proven elsewhere in the transit industry.

The following rationale and criteria were considered in making replacements with new equipment, technology, and operational improvements.

- Performance - should be greater than or equal to that provided by the present equipment. Includes availability, reliability, capacity, travel time, and efficiency.
- Interface with Other Equipment - should be compatible, both physically and electronically.
- Safety - should be greater than or equal to that provided by present equipment.
- Aesthetics - should be acceptable.
- Application - should be appropriate. For example, the addition of a vehicle capable of 80 mph speeds to a system having civil speed constraints to 30 mph due to track geometry or station spacing would be an improper application of that vehicle.
- Sophistication - replacements should not be effected with more sophisticated parts, simply for the sake of sophistication. For example, replacement of mechanical switch machines, in kind, may be totally satisfactory.
- Standardization - replacements should be in the direction of standardization, but the impact of the change on functions or performance should be minimal.

- Technological Risk - should be appropriate for the function to be performed. For example, fiber optics may present unacceptable risks for signal and control systems at present, but could be perfectly acceptable for data transmission to monitors for CCTV security systems.
- Interruption to Existing Transportation Service -should be minimal and/or acceptable.
- Availability of Equipment -replacement elements, subsystems, or components should be available within acceptable time periods and costs.

The foregoing discussion suggests the strategies and decision rules that governed the choices of specific improvement actions. Through close coordination with the transit authorities and applications of these principals, appropriate projects for modernization, rehabilitation and refurbishment were selected for inclusion in the list of proposed capital improvements for each transit system.

o Performance Data
As previously indicated various performance data and indicators were collected in order to assist in defining the types of improvements that should be considered in this rail modernization program. These included such performance data as the following:
- Safety performance data includes the number of derailments per million car miles of revenue service, the number of on-board injuries due to car-related conditions per million car miles.
- Reliability/availability performance data includes percent of train trips not on time due to track failures/ deficiencies, mean time to repair for cars, mean time to restore service, percent of vehicle fleet that can be serviced by the maintenance facility at any one time.
- Performance data for operating efficiency includes the annual car operating maintenance costs per car mile, average annual operating and maintenance costs for the entire power distribution element per car mile, average annual operating and maintenance costs for the maintenance facility per square foot.
- Performance indicators for security include the number of annual security incidents (i.e., trespassing, vandalism, etc.) near stations, track and associated right-of-way facilities, number of annual security incidents in the yards and shops.
- Performance data for aesthetics include the vehicle-generated noise levels, noise levels in the stations, air and water pollution emissions produced by maintenance facility activities.

2.5 GENERAL CONCEPTS FOR DEVELOPING BASIC COST ESTIMATES

o Concept.
The fundamental procedure, used in developing the overall cost estimates was to determine cost estimates at the project level for each transit system element. These individual estimates were compiled into totals for each transit system, then for each geographical area and finally for all systems.

There are three reasonably well defined levels of cost estimation detail and accuracy. These are:

1. Order of magnitude estimates;
2. Budget estimates;
3. Final design estimates.

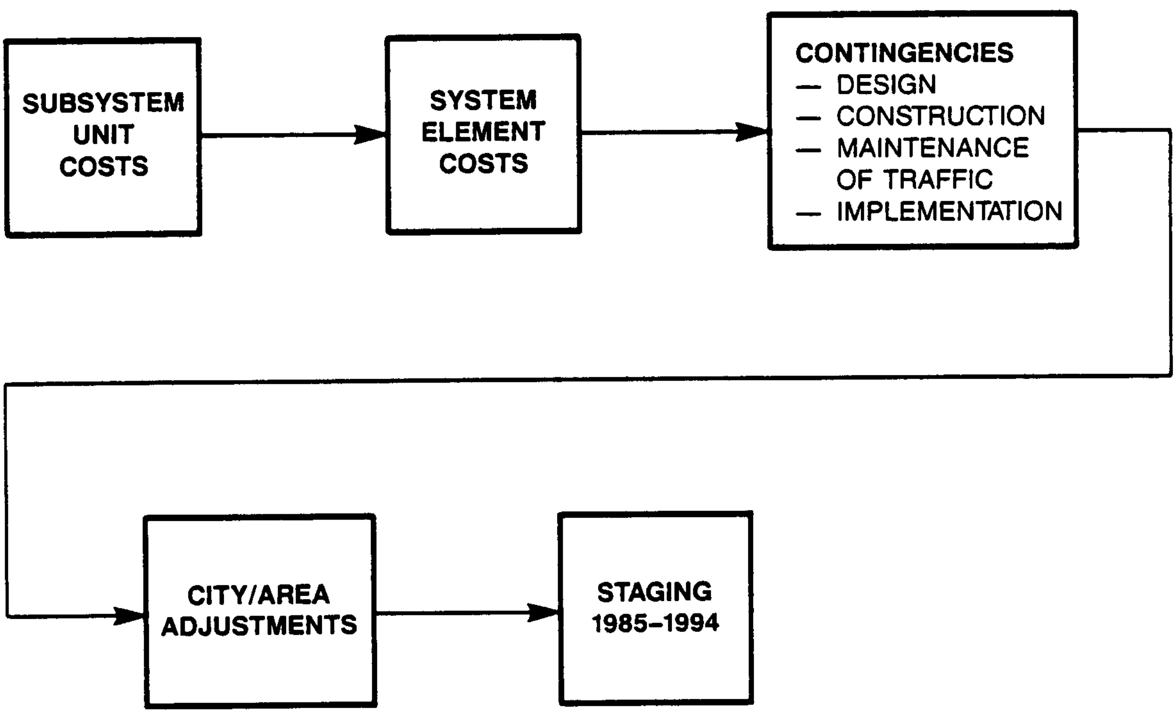
The Rail Modernization Study has primarily utilized the second level, budget cost estimating. This level is a combination of partial quantitative analyses and historical in-place costs. The detail at this level is adequate and appropriate for making decisions concerning project feasibility and for developing overall rail modernization cost estimates.

The general procedure for developing the basic cost estimates is provided in Figure 2.1. After the projects and proposed level of improvement were identified, the subsystem unit costs were developed. The system element costs were determined by combining the unit costs with the quantities required for each proposed improvement (i.e., miles of track, number of vehicles, substations, etc.). Various contingencies were then evaluated for each improvement project and the value estimated for each contingency.

Revised cost estimates were then adjusted for the city or area served by the transit system. The staging of each proposed improvement project was then estimated and annual costs derived.

Figure 2.1

PROCEDURE FOR DEVELOPING BASIC COST ESTIMATES



The development of the budget cost estimates involved analyses of technical requirements, on-site appraisals, and preparation of schematic designs to establish quantities requiring improvements. Cost data were derived from a variety of sources: estimates from major equipment suppliers, recent bids, final design estimates on similar projects, and the actual cost of recent vehicle or other equipment purchases. Emphasis was placed on the use of actual published costs in developing unit cost values. Unit cost values were also obtained from such sources as: Means Mechanical and Electrical Cost Data, Dodge Digest of Building Costs and Specifications, Building Cost File (Van Nostrand Reinhold Company), Heavy Construction Cost File, Engineering News Record, Richardson Engineering Services, Inc. The differences in construction costs among the surveyed rail installations were initially estimated by using the City Geographical Adjustment Index and other suitable comparative indices.

After compilation of basic costs, variations were evaluated to determine reasons for the observed ranges in costs for ostensibly similar improvements. Here the experience of the transit industry proved invaluable. The capital costs for major rehabilitation projects were solicited from operating authorities which are currently involved in such projects. Useful data were also provided by authorities involved in replacing or rebuilding vehicle subsystems. In situations where adequate confidence could not be obtained on the costs of subsystems or components, it was necessary to evaluate combinations of subsystems or the whole system element.

Another primary source of cost data for specific refurbishment, rehabilitation, and modernization projects was information obtained during the physical inspection of each transit property.

The development of budget cost estimates recognizes that the primary purposes of these estimates are to provide an estimate of the capital costs for modernizing, rehabilitating, and refurbishing the rail transit facilities. After development of the basic cost estimates, several contingencies and escalation factors were applied to make estimates as valid as possible. Here the purpose was to reduce the uncertainties associated with projecting capital costs over a ten-year period during which systems continue to deteriorate through use and the fact that construction costs could change at a rate different from inflation.

- Procedure for Developing Basic Cost Estimates.

Cost estimates were developed to the level of detail necessary to provide confidence in the estimate. For this study, emphasis was placed on the preparation of cost estimates at the subsystem level of detail. However, cost estimates for system elements, components, and equipment were developed to the extent possible and where necessary to provide support and confidence in the basic cost estimate. When the costs of the whole system element provided the most reliable estimate, these costs were used and the individual components included in the improvement were only indicated.

Individual unit prices were the primary basis for all cost estimating. These unit prices incorporated the costs of material, labor, insurances, taxes, and a contractor's overhead, profit and construction supervision. In other words, all costs associated with the actual on-site installation of the system element, component, or equipment.

The procedure used in developing cost estimates recognized that costs would differ for different levels of improvement for each element. The general categories of improvement (modernization, rehabilitation, and refurbishment) were defined. Seven levels of improvements within these three categories were established. The scope of work for each level of improvement was defined for each system element. These definitions provided the basis for cost estimates for the different levels of improvement. They also made possible a consistent approach to the estimates among the system elements.

Another consideration was the level of detail that could reasonably be obtained for developing unit cost estimates. It was found that this information varied considerably for each of the different system elements. For example, track improvements were found to be relatively straight forward and unit costs could be obtained for each of the major subsystems: rail, rail joints, rail fasteners and anchors, ties/crossties, and ballast.
Reasonably detailed unit cost estimates were also available for improvements to maintenance facilities and related appurtenances. However, vehicle, power distribution, and system-wide control improvements were found to be less straightforward. It was more difficult to separate the costs of known improvement packages into detailed unit costs. As a result, the unit costs of these improvement packages at the system element level received primary consideration. The unit costs of station improvements were also difficult to break down because of wide variations in known improvement costs.
Therefore, a slightly different approach was used to estimate these unit costs. The general procedure was to summarize the costs of a relatively large number of recent station improvements according to the different levels of improvement specified by the definitions. A computer program was used to plot these summaries of known costs versus the physical size of the station. By using a "least squares" approximation technique, a curve indicating cost per square foot was developed for each level of improvement for each station type: historical, subway, elevated, at-grade, commuter/LRV stop.

The most difficult unit costs to obtain were those for bridges, The paucity of cost information was due to the wide variety of the types of bridges and structures, the age of the installations, and lack of records. As a result, a series of mathematical equations were developed and compared to recent bid and construction costs. These equations were based on sound engineering design principles and utilize two primary variables; span length and deck area. The constants in the equations were adjusted so that the results could be calibrated to known 1983 cost estimates. The equation most applicable to the type of bridge or structure being improved was then used to estimate the cost of each improvement.

- Contingencies.

  Several types of contingencies were incorporated into the cost estimation procedure: a design contingency, a construction contingency, a maintenance of traffic provision, and an implementation contingency.

  - Design Contingency

    A design contingency is required when an improvement project is sufficiently large that preliminary engineering and final design are required to implement the project. Engineering design is necessary for major construction projects, for rehabilitation and reconstruction, and for the procurement of vehicles and other large capital equipment.

    The design contingency varies for different phases of project design and depends upon the details included in available information, details included in the design criteria, and scope of work to be performed.

    Modernization, rehabilitation and refurbishment projects which do not require a complete engineering design would have an appropriately lower design contingency. For example, the rehabilitation and refurbishment of existing facilities would probably not require as complete an engineering design as would new construction. Design contingencies for the procurement or rehabilitation of vehicles would be less than for facilities construction because the vehicle work is repetitive. The percentage used for the design contingency was based on recent experience with similar types of project improvements. As a result, the following percentages were used as guidelines in estimating the magnitude of this contingency:

Level of Improvement	Recommended Design Contingency
1	15.0%
2	12.5%
3	10.4%
4	8.7%
5	7.2%
6	6.0%
7	5.0%

  - Construction Contingency

    A construction contingency for anticipating unforeseeable costs after the award of a contract, is also included in the total estimated project cost. This contingency is normally a percentage of total estimated construction cost to cover such construction-related items as spot overtime, bad soil conditions, weather, subcontractor's performance, right-of-way acquisition, and other similar types of known but non-quantifiable factors. Expressed as a percentage of the estimated construction cost, the contingency values vary from two to ten percent, depending on the elements being bid as separate contracts and local conditions that could change the complexity of the installation.

  - Maintenance of Traffic Provisions

    The costs of maintaining transit operations during the implementation of a specific project were also considered in estimating the percentages to be used for this contingency. These costs are those associated with such items as: working only at night, on weekends or during other low-volume periods; constructing by-pass tracks; providing protective barriers and canopies in stations; and providing substitute service. Although these "maintenance of traffic provisions" are primarily applicable to track and structure improvements, they may also be applicable to some types of power, system-wide control, and maintenance facility improvements. It has been assumed that this contingency is most closely related to the density of traffic on the rail line and to the peak period directional movement of passengers. Since statistics to develop a generalized procedure for this contingency are not obtainable, maintenance of traffic provisions were developed on a "case-by-case" basis and the rationale for the selection of specific percentages, when applicable, were provided with the cost estimate.

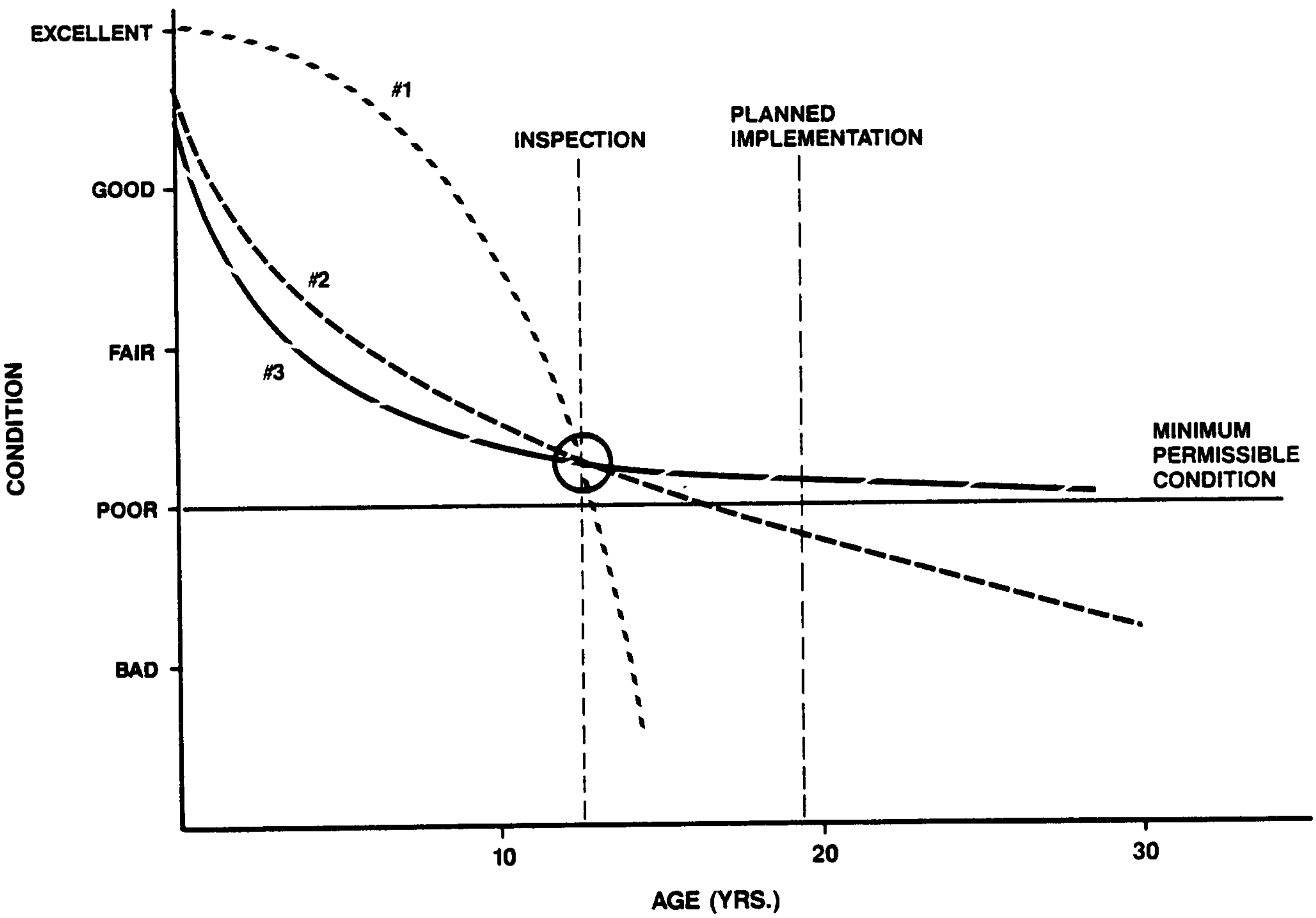
- <u>Implementation Contingency</u>

  This contingency is related to the continued deterioration of a system element from the time that it was inspected to the time the improvement is to be implemented. The problem is illustrated in Figure 2.2 and could be of either minor or major concern in developing the cost estimates or the time of implementation. In the illustrated example, it has been assumed the "minimum permissible condition" is condition 2 (poor). At this condition, frequent major repairs (less than six months between major repairs) could significantly increase maintenance costs and lead to major potential operating problems. In the example in Figure 2.2, a rate of deterioration similar to that implied by curve #3 would result in minor deterioration of the system element between the time the element was inspected and the date planned for implementing improvements. However, a rate of deterioration similar to that implied by curve #2 would result in additional costs (ie: the proposed level of improvement would change) and the minimum permissible condition would be exceeded before the planned project implementation date. A rate of deterioration similar to the one implied by curve #1 would require immediate action, funding, and implementation. (This type of analysis is used in Section 3.4 of the report.)

  The magnitude of this contingency is related to the lapse in time between the date the inspection was conducted and when the improvement is to be implemented, as well as the rate of deterioration during that time period. For example, a project that will begin and end in 1986 would probably have a smaller implementation contingency than one that is scheduled for completion in 1990. In order to determine the value of this implementation contingency, some insight into the deterioration rates for the various system elements was necessary. To estimate the remaining life and deterioration rate of the different system elements, procedures were employed that were used to develop the "Iowa Type Survivor Curves." (These procedures are

Figure 2.2

SYSTEM ELEMENT DETERIORATION



published in Statistical Analysis of Industrial Property Retirements by Robley Winfrey, Bulletin 125, published by Engineering Research Institute of Iowa State University, revised 1967.) Since the deterioration rate for each system element is different, an average deterioration rate for each system element was calculated by using linear regression techniques. In all cases, a "straight line fit" was determined to be statistically acceptable (i.e., a correlation coefficient greater than .98). The deterioration rate (change in remaining life per year) times the difference in time between the time of inspection and time of implementation was divided by the design life and then multiplied by 100 to provide a percentage value. This percentage value represents the probable percent change in the physical condition between the time of inspection and implementation and was defined as the implementation contingency. The total cost of each improvement project was then increased by the calculated percentage.

- City Adjustments.
  A basic improvement project cost estimate was developed from the quantities, unit costs and application of the various contingencies described above. After this basic cost estimate was verified, it was further adjusted to reflect the differences in costs that prevail between cities and regions of the United States. These adjustments were made in accordance with such indices as the City Geographical Adjustment Index (R. S. Means Co., Inc., Building Construction Cost Data (1983), Section 19).
- Staging.
  The adjusted total project cost was staged over the years during which the improvements were proposed to be accomplished. Staging depends upon a number of considerations including: availability of equipment or facilities to be worked on, condition of the element and need for improvements prior to serious deterioration, and allocation of resources with which to accomplish the improvements. After staging, project costs were escalated as described below.

2.6 GENERAL CONCEPTS FOR DEVELOPING COST EFFECTIVENESS PRIORITIZATION

Extensive information and data collected during the Engineering Cost Estimate Phase of this study were used to develop and apply an initial mechanism for determining the priority order of rail transit improvement actions within each transit system. This methodology included an assessment of the costs and benefits of the proposed improvement actions.

The primary objective of this analysis was to obtain a priority listing of the proposed improvement projects together with an assessment of the related benefits and capital costs. The general concepts for developing this cost-effectiveness prioritization are as follows:

- Two different methods of estimating cost effectiveness were developed. Both methods involved dividing the different types of transit systems into identifiable and logical segments/branches. Passenger miles, as a measure of passenger utilization, were estimated for each of these segments/branches. One cost-effectiveness method used the ratio of passenger miles to capital cost as a means to compare the relative effectiveness of improvements on each of the segments/branches. The other method used unit benefit modifiers developed by LTI to estimate operating cost savings and passenger benefits (in dollars) attributable to proposed capital improvements on each segment/branch. The sum of operating cost savings and passenger benefits divided by the cost of improvements for each system element provides a benefit/cost ratio for each improvement project on each segment/branch. Summarizing the benefit/cost ratios for all the project improvements on each segment/branch provides an initial estimate of the cost effectiveness of all the proposed improvements on each branch/segment.

- Each transit system was divided into identifiable and logical portions of the total rail system for further analysis. In general, these segments are identifiable branches of the transit system.

- An assessment of the condition of each system element (i.e., track, vehicles, power distribution, etc.) was conducted on each system segment. The estimated condition was obtained from data available in the data base from the Engineering Cost Estimate Phase of this study. In addition to the present condition of each system element, the improved condition and age of each system element for each proposed improvement was determined.

- For each system element on each segment, the cost to undertake the improvement project was determined from the data base.

- For each transit system segment, an estimate of the utilization on that segment was determined. This utilization is expressed in terms of passenger miles and was obtained from a comprehensive evaluation of the total passenger miles estimated by each transit system.

- The cost effectiveness for each proposed improvement was determined by obtaining estimates of the benefits and costs in terms of its utilization in improvement and condition. This assessment provides a prioritized list of improvement actions in accordance with their cost effectiveness. As a result, the cost-effectiveness measure accounts for the benefits expected for each improvement project as well as the utilization on each segment.

- Using the relationship between benefits and costs, an ordered listing of improvements to each segment was determined. The final result provides a prioritized listing of improvement actions on each system segment and a resultant prioritized listing of all of the segments on all of the transit systems evaluated.

- An assessment of the prioritized listing of improvement actions on each segment was obtained, and an evaluation of the benefits for various capital expenditure levels was developed. The results reflect the amount of condition improvement which would be derived from various levels of funding and for various levels of benefit.

3.0 CURRENT CONDITION OF RAIL TRANSIT SYSTEMS

3.1 GENERAL PROCEDURE FOR ESTABLISHING THE CURRENT CONDITION

The primary purposes of this chapter are to provide a summary of the results of the physical assessments of each transit system and its elements. Also provided is the statistical information that indicates the rate of depreciation/deterioration of various system elements and the impact that corrective action could have on this deterioration.

In order to ensure the ultimate credibility of the study results, definitive requirements were developed for the physical assessment of each rail transit system. During the early tasks of the study, considerable effort was devoted to:

- o Developing the procedures for these inspections.
- o Establishing methods and definitions for determining estimate of the existing condition of each system element and subsystem.
- o Designing data collection forms/notebooks for the on-site inspections.
- o Determining assessment schedules and personnel assignments.
- o Establishing assessment requirements, including the description and use of the data collection forms.
- o Developing computer input forms and supporting information that would be collected, compiled, summarized, and evaluated to present reasonably comprehensive information on the current condition and status of each transit system and system element.

The physical survey of the various system elements and subsystems was necessarily done by developing sampling techniques, since it was neither feasible nor essential to conduct a survey which examined 100 percent of all of the equipment and facilities. Statistical estimation techniques were developed and used to reduce the sample size/number or amount of subsystems inspected while still providing a relatively high level of confidence in the final estimates. The first technique used was to stratify the sample, that is to group common elements together and sample or inspect small numbers in each group with similar characteristics. For example, track, vehicles, power distribution, system-wide controls, stations, structures and maintenance facilities were divided into groups by type, size, age and other distinguishing characteristics. In some situations, this stratification permitted relatively small numbers of subsystems to be inspected since the results could be extrapolated with reasonable confidence. However, in other situations the stratification resulted in the inspection of most of the subsystems in a system element; this was especially true for maintenance facilities and power substations, where the differences in size, type of equipment, usage, and age were sometimes extensive. As a result, it was necessary to inspect most of the maintenance facility buildings and almost 50 percent of the power substations. On the other hand, this type of stratification permitted a relatively smaller number or percentage of vehicles, stations and bridges to be inspected since large numbers of the same type were often obtained or built during a reasonably short period of time (i.e., a few years).

In conjunction with the development of the inspection procedures, a consistent set of definitions for establishing the condition of each system element were developed. The general definitions, that were applied to all system elements, are provided in Table 3.1.

TABLE 3.1

General Definitions of Condition Codes

Condition Code	Category	Definition
1	Bad	In sufficiently poor condition that continued use presents potential problems.
2	Poor	Requires frequent major repairs (less than six months between major repairs).
3	Fair	Requires frequent minor repairs (less than six month between repairs) or infrequent major repairs (more than six months between major repairs).
4	Good	Elements are in good working order, requiring only nominal or infrequent minor repairs (greater than six months between minor repairs).
5	Excellent	Brand new, no major problems exist.

The general definitions were used as guidelines for developing more specific definitions for each system element. Some examples of these definitions are provided in the following paragraphs.

- Track

The definitions used for assigning condition codes for the rail subsystem are as follows:

Condition Code	Category	Definition
1	Bad	Rail condition unsatisfactory - needs immediate replacement because it presents a serious hazard (i.e., rail head broken off, web failure; etc.).
2	Poor	Frequent observable rail flaws (non-serious surface defects) or high wear (i.e., < 50 percent of original rail head section remaining); rail which should be replaced within the next one to five years.
3	Fair	Some rail flaws or moderate wear (i.e., 50 to 75 percent of original rail head section remaining); rail which should be replaced within the next six to ten years.
4	Good	Few rail flaws or slight wear (i.e., > 75 percent of original rail head section remaining); rail which should not require replacement within next ten years.
5	Excellent	Essentially brand new rail with no flaws and negligible wear.

Similar types of definitions were developed for rail joints, rail fastening and anchor systems, crossties, ballast and subballast, special trackwork and machinery, track alignment and gauge, track surface, roadbed/embankment and cut slopes/vegetation, drainage, fencing, and grade crossings. In the summary evaluation, it was assumed that the rail condition includes the condition of the rail joints, fastening and anchor systems, ties and crossties, ballast and subballast, etc.

o Vehicles

The definitions for assigning condition codes to electrically self-powered cars are as follows:

Condition Code	Category	Definition
1	Bad	o Major deterioration in the form of structural corrosion, extensive surface corrosion, leaking roof doors or windows, rotted flooring, broken or cracked truck frames, oil or water in the air system. o _Any_ failure in service of the brakes, suspension, or train control. o Frequent failures in service of doors; heating, ventilation, air conditioning (HVAC), motors, controllers, or motor-alternator. o Obsolete because parts are unavailable for doors, HVAC, propulsion, brakes, or electrical equipment. Car is unable to interchange with others in the fleet of the same type.
2	Poor	o Deterioration in the form of surface corrosion, scratched or opaque windows, worn floor covering and upholstery. Worn truck components, including bearings, liners, wheels and axles. Inaudible PA system. o Frequent failures in service of doors, HVAC, motors, controllers, or motor-alternator. o Obsolete electronic equipment.
3	Fair	o Deterioration in the form of scratched or opaque windows, worn floor covering, worn shock absorbers. o Occasional failures in service of doors, HVAC, motors, gears, controllers, motor-alternator. o Obsolete electronic equipment.
4	Good	o Minor deterioration in the form of scratched windows, worn seats and floors, worn brake shoes, motor brushes and contactors. Some wheel flats. o Very few service failures of any equipment.
5	Excellent	o Essentially new condition.

Similar types of definitions were also developed for unpowered cars, locomotives, and diesel cars. The vehicle condition includes the condition of the structure, traction power, electrical/electronic systems, and miscellaneous car equipment.

o Power Distribution

The definitions used for assigning condition codes to power substations are as follows:

Condition Code	Category	Definition
1	Bad	Major equipment (high voltage AC switchgear, transformers, rectifiers, feeder breakers, auxiliary support equipment) of substations is older than its design life and spare parts are not available (equipment design is obsolete or substation capacity is not adequate for the peak load requirements.
2	Poor	A single major substation component is "state of the art" and recently installed. The remainder is nearing the end of its design life. Spare parts are not available for some of the major components.
3	Fair	Age of equipment is nearing midpoint of useful life or from 50 to 75 percent of major substation components are "state of the art" and recently installed. The remaining equipment is nearing the end of its design life. Spare parts are becoming unavailable.
4	Good	Major equipment of substation is "state of the art" but has been in service for over ten years. Equipment may require little or minor component substitution to achieve original levels of reliability.
5	Excellent	Major equipment of substation is new (installed within the past ten years). No problems exist.

The condition ratings for the categories of circuit breaker houses, switching stations, and gap breaker stations are comparable to those defined above for the substations.

Similar types of definitions were developed for feeder cables, duct banks, overhead wire, poles and foundations, and third rail. The condition of the other subsystems and components were included.

- System-Wide Controls

The definitions developed for the inspection of the system-wide controls system were based on the inspection of individual equipment in order to determine the condition of these relatively complex major subsystems.

The collected information was then utilized in the aggregate to determine the general condition of the entire major subsystem or principal component. As a result, the specified condition may represent an average of the conditions of many components or associated items, or be largely based upon the condition of a few (or even one) especially critical components or items.

The definitions used for assigning condition codes to solid state circuitry are as follows:

Condition Code	Category	Definition
1	Bad	Inoperative. Obviously worn-out or broken items which would preclude proper operation.
2	Poor	Poor physical appearance. Dirty, worn materials, loose mountings, "temporary-type repairs", considerable evidence of repair.
3	Fair	Generally "acceptable" appearance. Minor amounts of dust acceptable. Circuit boards may evidence repairs; resoldering must be neat and all surfaces resealed. Can have some repairs and/or circuit modifications not up to the standard of the original as-built equipment.
4	Good	Good overall appearance. Clean, with no evidence of significant repairs to, or substitution/replacement of devices. Circuit boards have no evidence of deterioration.
5	Excellent	Brand new, no evidence of problems or repairs.

Similar types of definitions were developed for relay circuitry, microprocessors/computers, interior cabling, exterior lines and cables, impedance bonds, insulated joints, electro-mechanical devices, indicators/displays/static boards, exterior and interior housings/cabinents/enclosures, radio equipment, radio antennas, television equipment, telephone and public address equipment, and control units/machines. The various equipment items were also grouped in accordance with whether or not they were part of the train control, communications or supervisory and control systems.

- Stations

The following definitions were used in conjunction with specified performance data to assign condition codes to the stations.

Condition Code	Category	Definition
1	Bad	Continued use presents a serious hazard.
2	Poor	Major repair required to prevent structural collapse and/or frequent major repairs required for most subsystems.
3	Fair	Major repairs or replacement required for some subsystems. Frequent minor repairs (less than six months) for remaining subsystems.
4	Good	Elements are in good working order, requiring only nominal or infrequent minor repairs (greater than six months between minor repairs). A few subsystems may require replacement.
5	Excellent	Brand new.

The more significant performance data, that was used to assist in assigning condition codes, included station ridership, accidents, and crime rates. The condition of each station also included the condition of the structure, horizontal circulation, vertical circulation, station amenities, etc.

- Structures and Facilities

The definitions, used for assigning condition codes to the structures and facilities, were based on the inspection of the physical components in order to estimate the condition of a complete bridge, structure or building. The collected information was then evaluated to determine the condition of the entire bridge or structure.

The definitions used for assigning condition codes to structural steel bridge components are as follows:

Condition Code	Category	Definition
1	Bad	Severe rusting and flaking on main members; section losses over 50 percent; totally disintegrated bracing, lacing.
2	Poor	Heavy rusting and flaking on main members; bracing and lacing deteriorated or missing. Members cracked.
3	Fair	General medium rusting; connection plates and bracing have section loss to 25 percent; spots of heavy rusting and flaking. Secondary members exhibit cracks.
4	Good	Light rusting of steel over all surfaces; no significant loss of section (less than ten percent of main component materials, i.e., web, flange, bearing angles, etc.)
5	Excellent	No visible deterioration of steel; some paint loss.

Similar types of definitions were developed for mechanical and electrical subsystems, concrete spall and rebars, concrete cracks, leaking, leaching, masonry, and timber. Detailed supporting definitions and instructions were also developed to assist in the inspection and assignment of condition codes.

- Maintenance Facilities

The definitions, developed for the inspection of the maintenance facilities, were based on the physical condition of the more important architectural, structural, mechanical, and electrical features of the buildings and associated equipments. The maintenance/storage yards were also evaluated with respect to the physical condition of the trackwork, drainage, signal and communication systems, site lighting, fire protection, and electrification.

The definitions used for assigning condition codes for the structural features are as follows:

Condition Code	Category	Definition
1	Bad	Structure has failed and/or deteriorated to the point that creates a serious hazard.

2	Poor	Structure requires frequent major repairs to function as intended.
3	Fair	Structure requires frequent minor repairs to function as intended.
4	Good	Structure requires infrequent minor repairs.
5	Excellent	Structure is brand new or no major problems exist.

o Summary

Upon completion of each physical inspection, the results were provided in individual memorandum reports on each system element and the pertinent information was also entered on computer input forms, as illustrated on the following page.

These forms provided the following type of information to be compiled for further analysis:

- The subsystem inspected (i.e., track section, type of vehicle, type of bridge/structure, etc.).
- The name of the transit system.
- The system code number.
- The name of the inspector.
- The total number or amount of the subsystems.
- The number or amount inspected.
- Any amplifying information on the subsystem, such as the specific type of subsystem.
- The dimensions.
- The total amount.
- The percent inspected.
- The year installed or purchased.
- The maintenance history (defined in section 3.4.2).
- Whether or not the subsystem has a history as a "problem subsystem" (i.e., greater or faster deterioration than expected).
- The design life of the subsystem.
- The present condition in terms of the five condition codes.

The results of each transit system inspection were then summarized in an individual transit system report on the current condition. These individual transit system reports are provided separately.

The following sections provide aggregate data and evaluation of the current condition of the transit systems.

RAIL MODERNIZATION STUDY INPUT FORM
GANNETT FLEMING TRANSPORTATION ENGINEERS, INC.

S U B S Y S T E M ☐☐☐☐

Transit System Name ______________________ System Number ☐☐

Inspector Name ______________________ Inspector Number ☐☐☐☐

Date (mmddyy) ☐☐☐☐☐☐

Total Number of Amount of Subsystems ☐☐☐

Number of Amount of Subsystems Inspected ☐☐☐

Amplifying Information ☐☐☐

Dimensions 1 = Each 2 = Lineal Feet 3 = Square Feet
4 = Board Feet 5 = Cubic Yards 6 = Miles ☐

Total Amount ☐☐☐☐☐☐☐

Percent Inspected ☐☐☐

Year Installed or Purchased ☐☐☐☐

Maintenance History 1 = Minimum 2 = Normal Preventive Maintenance
3 = Corrective Maintenance 4 = Major Corrective Maintenance ☐

Problem Subsystem 1 = Yes 2 = No ☐

Design Life (years) ☐☐

Estimated Life Remaining (years) ☐☐

Present Condition (1 through 5) ☐

3.2 GENERAL FINDINGS WITH RESPECT TO THE CURRENT CONDITION OF THE MAJOR SYSTEM ELEMENTS

The characteristics of the major system elements and subsystems inspected are provided in Table 3.2 by type of rail transit system.

TABLE 3.2

CHARACTERISTICS OF TRANSIT SYSTEM ELEMENTS INSPECTED

Major System Element/Subsystem	Quantity	Type of Transit System Rapid	Light	Commuter	Total
Track	Miles	1,430	369	3,303	5,102
Vehicles					
- Self Propelled	Each	9,531	873	2,559	12,963
- Locomotives	Each			416	416
- Unpowered	Each			1,671	1,671
Power Distribution					
- Substations	Each	456	60	157	673
- Overhead Wire	Miles	70	470	811	1,351
- Third Rail	Miles	1,378	28	489	1,895
System-Wide Controls	Each	11	7	11	29
Stations					
- Historic	Each	11	4	27	42
- Subway	Each	419	29	4	452
- Elevated	Each	313	2	60	375
- At Grade	Each	132	51	530	713
- Station Stops	Each	0	294	350	644
Structures and Facilities					
- Highway Bridges	SF x 1000	494	110	1,583	2,187
- Transit Bridges	SF x 1000	1,342	178	0	1,520
- Railway Bridges	SF x 1000	0	92	7,560	7,652
- Elevated Bridges	LF x 1000	1,076	6	93	1,175
- Tunnels	LF x 1000	1,537	59	68	1,664
Maintenance Facilities					
- Buildings	Each	102	16	35	153
- Yards	Each	59	12	61	132

The general findings, with respect to the current conditions of each of the major system elements or subsystems, are provided in the following sections of this report. These findings provide the basis for the development of the proposed repair and replacement actions and the associated capital cost estimates in the chapters which follow.

3.2.1 SYSTEM ELEMENT AND SUBSYSTEM CONDITION SUMMARIES

A reasonably comprehensive summary of the current condition of each transit system and proposed improvement programs are provided in individual transit system condition reports. This information has been summarized by type of transit system for each system element or major subsystem on the condition descriptions, which follow. The condition categories are the same as defined in Table 3.1 and then amplified for each system element.

TRACK FINDINGS

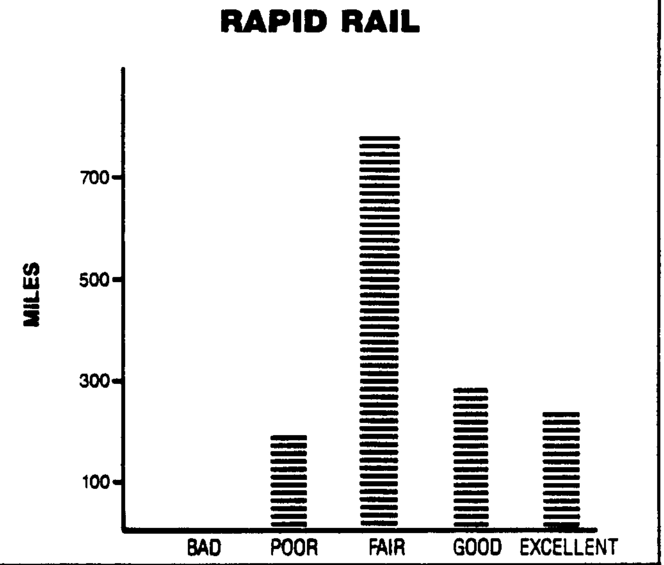
The inspected transit systems have approximately 5,102 miles of track: 28 percent of this track mileage is on rapid rail systems, 7 percent on light rail systems, and 65 percent on commuter rail systems. The results of the physical inspections are provided in accompanying condition diagrams.

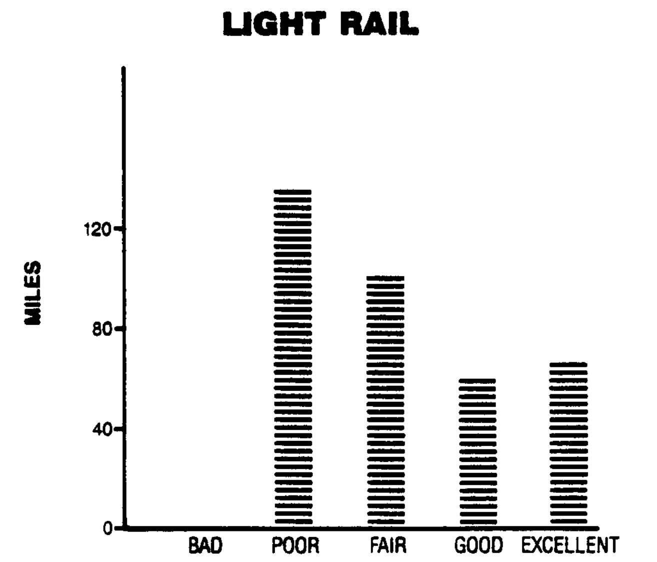
Of the 1,430 miles of rapid transit track, less than 200 miles is in "poor" condition, about 800 miles is in "fair" condition, and the remainder is either in "good" or "excellent" condition. The light rail systems contain only about 369 miles of track, but nearly 140 miles is in "poor" condition, 109 miles is in "fair" condition and the remainder is in "good" or "excellent" condition. The commuter rail systems contain about 3,303 miles of track and about 1,650 miles is in "fair" condition with most of the remainder in either "good" or "excellent" condition.

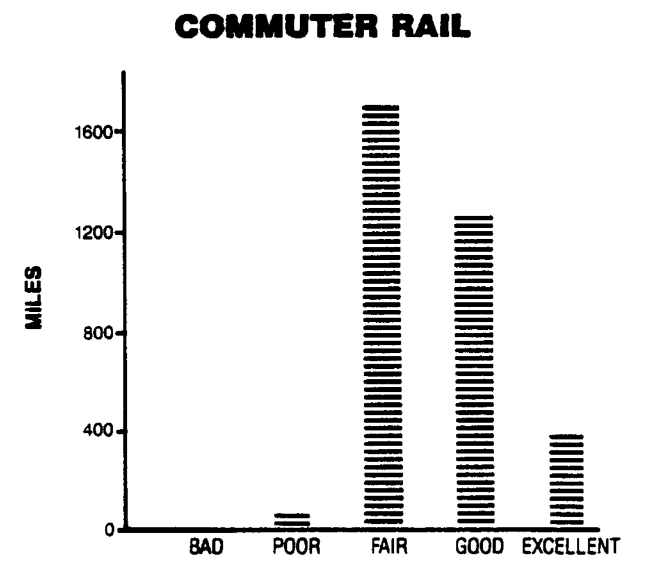
The rail itself, on the rapid rail systems, is in generally "fair" condition. Cut and screw spike fastening systems are also in "fair" condition. Newer types of spring clip and direct fixation fasteners are being tested; the spring clip fasteners were observed to be in excellent condition in most locations, but major problems were observed with some types of direct fixation fasteners. In general, the older timber ties are in poor condition and being replaced with either new timber or concrete ties. The ballast and subballast on some of the older systems, is in "fair" to "poor" condition and fouled to the point where drainage is becoming a serious problem, especially in subways.

The light rail systems have essentially the same problems as rapid rail, especially on older transit systems; this accounts for the higher percentage of track in "poor" condition.

The track for commuter rail systems is generally in better overall condition than other types of transit systems, although some rail exhibits end batter, corrugations, rail head defects, missing rail anchors, fouled ballast and some areas require additional ballast.





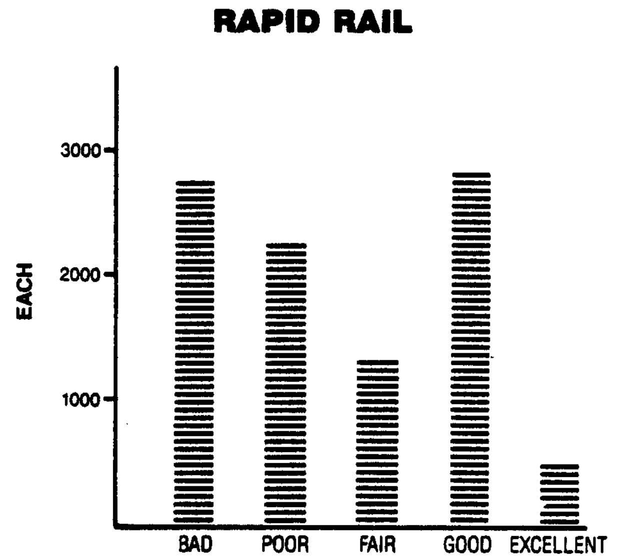


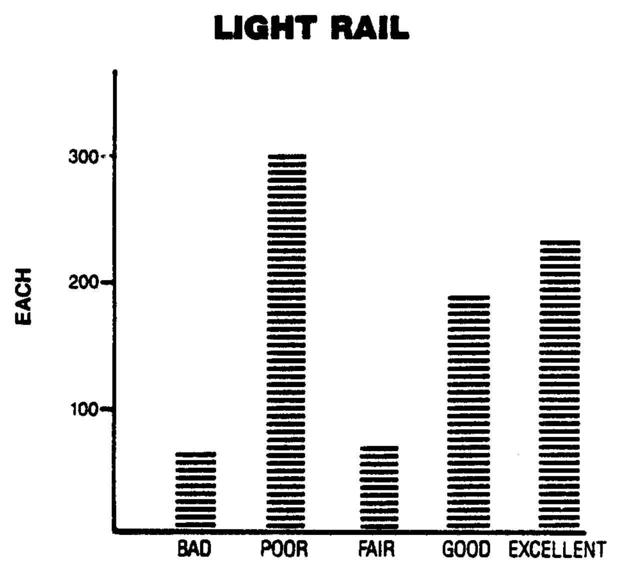
VEHICLE
SELF-PROPELLED RAIL CAR FINDINGS

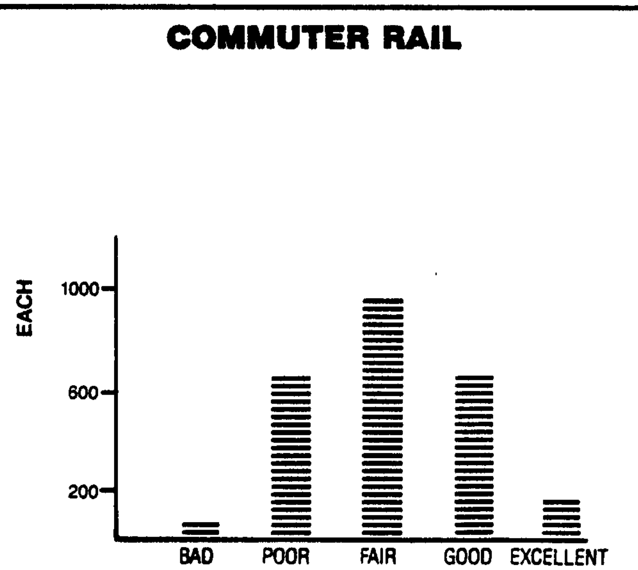
The inspected transit systems operate about 12,963 self-propelled rail cars: 74 percent on rapid rail systems, 7 percent on light rail systems and 19 percent on commuter rail systems. The inspection emphasized a comprehensive evaluation of structure, electrical/electronic systems and miscellaneous car equipment. The results of the physical inspections are provided in accompanying condition diagrams.

Of 9,531 rapid rail cars more than 2,700 are in "bad" condition, approximately 2,200 are in "poor" condition, approximately 1,300 are in "fair" condition and the remainder are in "good" or "excellent" condition. The light rail systems include 873 self-propelled cars and about 43 percent are in either "bad" or "poor" condition and will require either modernization or rehabilitation in the near future. The commuter rail systems contain 2,559 self-propelled vehicles and nearly one-third are in either "bad" or "poor" condition (29 percent).

The primary reason for the "poor" and "bad" condition of the self-propelled cars is age; almost 4,000 are over 22 years old. The structures and traction power are often in "poor" condition and deteriorating floors and controller service failures were identified as major problems. In addition, electrical and electronic subsystems were generally in "poor" condition and rewiring is required. Corrosion due to insufficient cleaning, salt spray in the winter, and outside storage is common. Couplers and draft gear are worn from years of use and the propulsion systems have deteriorated and become major maintenance problems. Replacement parts, for these older cars, are often difficult to obtain and some transit systems have had to develop an engineering design and manufacturing capability to meet even normal spare parts replacement requirements. The car trucks, traction motor supports, and attachment of accessories have all presented serious long term maintenance problems.







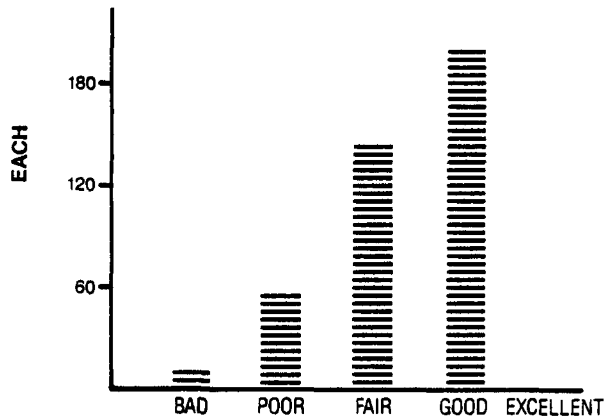
VEHICLE
LOCOMOTIVE/UNPOWERED RAIL CAR
FINDINGS

There are 416 locomotives and 1,671 unpowered cars and all are operated by the commuter rail systems. The results of physical inspections are provided in accompanying condition diagrams.

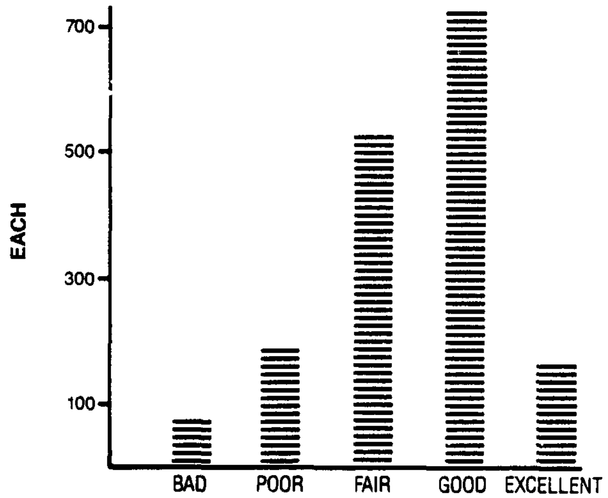
Less than 20 percent of the locomotives and 13 percent of the unpowered cars are in "bad" or "poor" condition. All of the "bad" locomotives are more than 22 years old, as are most of the locomotives identified as being in "poor" condition. However, some locomotives (4) were still in "fair" condition after more than 20 years of service. All of the locomotives (204) in "good" condition were less than 15 years old. Although 27 of the unpowered cars in "bad" condition were more than 30 years old, 23 of these cars were less than 10 years old. Unpowered cars in "excellent" condition were all less than 10 years old; those in "good" condition were all less than 15 years old. However, 124 of the unpowered cars that were over 30 years old were still in "fair" condition.

The basic problem in maintaining locomotives and unpowered coaches in "good" or even "fair" condition is deterioration of the frame and equipment. The steel framing, under stainless steel sheeting, is rusting. Locomotives that were rebuilt have become unreliable in less than 5 years and spare parts are difficult to maintain and acquire. When spare parts are no longer produced, the commuter rail system will most likely "cannibalize" parts from some vehicles in order to keep the others operating.

LOCOMOTIVES



UNPOWERED CARS



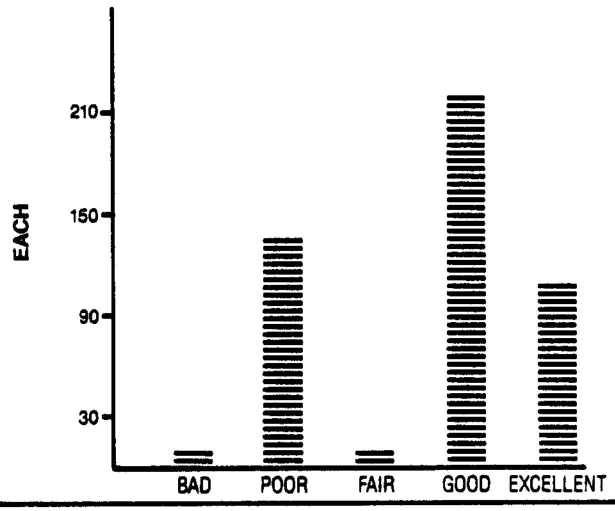
POWER DISTRIBUTION SUBSTATION FINDINGS

There are 673 power substations: 68 percent on rapid rail systems, 9 percent on light rail systems, and 23 percent on commuter rail systems. The results of the physical inspections are provided in accompanying condition diagrams.

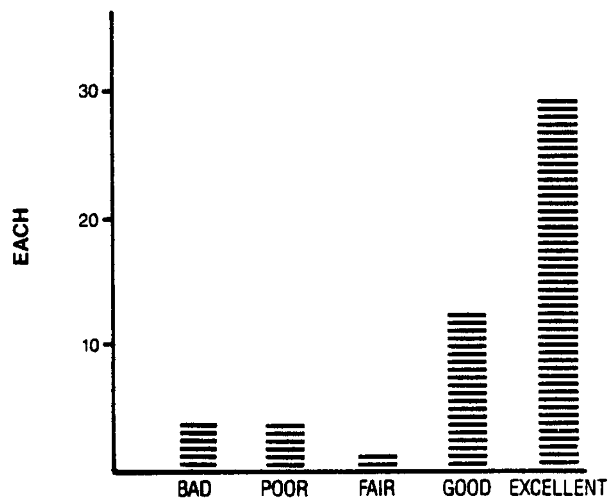
Of 456 substations on rapid rail systems, approximately 30 percent are in "poor" or "bad" condition and most are in "good" or "excellent" condition. Ten percent of the 60 substations on light rail systems are in "poor" condition and 12 percent are in "bad" condition. However, the commuter rail systems have about 30 substations that are in "bad" condition and nearly 20 that are in "poor" condition. Almost all of the substations that are in "poor" or "bad" condition are more than 35 years old and all of those in "excellent" condition are less than 15 years old. However, some of the substations that were nearly 25 years old were still in "good" condition and some (8) were in "fair" condition after more than 50 years of utilization.

Although very good normal maintenance programs were found throughout the transit industry, some of the current equipment is no longer manufactured and available. For example, approximately 15 percent of the NYCTA substations have rectifiers that were built before 1920 and 43 percent were built before 1950; more than 110 of these substations are in "poor" condition. High voltage equipment, transformers, D.C. distribution equipment, and power feed getaway cables that were installed before 1950 would have to be replaced.

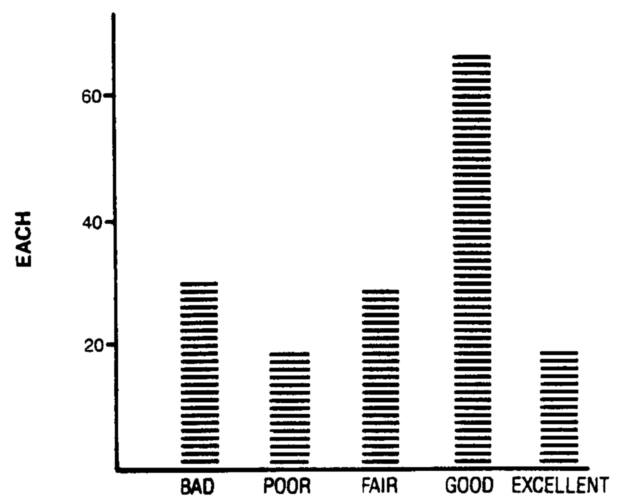
RAPID RAIL



LIGHT RAIL



COMMUTER RAIL



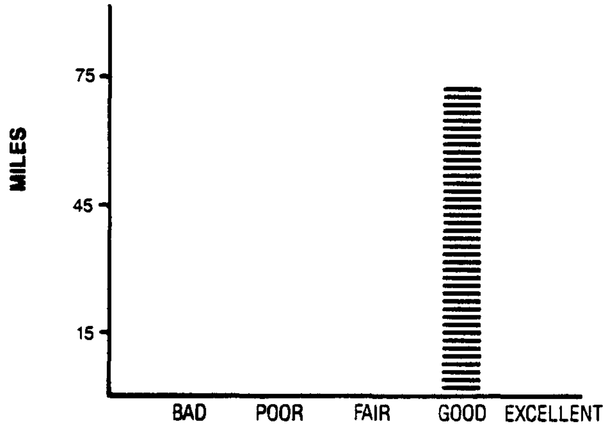
POWER DISTRIBUTION OVERHEAD WIRE FINDINGS

The inspected transit systems contain 1,351 miles of overhead wire: 5 percent on rapid rail, 35 percent on light rail, and 60 percent on commuter rail. The results of the physical inspections are provided in accompanying condition diagrams.

All of the overhead wire on rapid rail systems was determined to be in "good" condition and most wire on the light rail systems is in either "good" or "excellent" condition. However, nearly 400 miles of the overhead wire on the commuter rail systems was estimated as being in either "poor" or "bad" condition and in need of replacement. All wire that is in "bad" condition is more than 50 years old and all wire in "poor" condition is more than 25 years old. Of overhead wire in "excellent" condition, all is less than 15 years old. However, some wire (21 miles) is still in "fair" condition after more than 35 years of utilization.

All overhead wire is being maintained by some type of normal maintenance program and the contact wire is renewed as needed and therefore is generally in "fair/good" condition. However, some of the main messenger wire is steel and was installed more than 50 years ago; it is generally in "poor" condition. The auxiliary messenger wire of pure copper was determined to have minimum wear, even after more than 50 years of service, and is in "fair/good" condition. In some situations, the catenary system has become a problem due to increased power requirements since its installation and would have to be replaced.

RAPID RAIL



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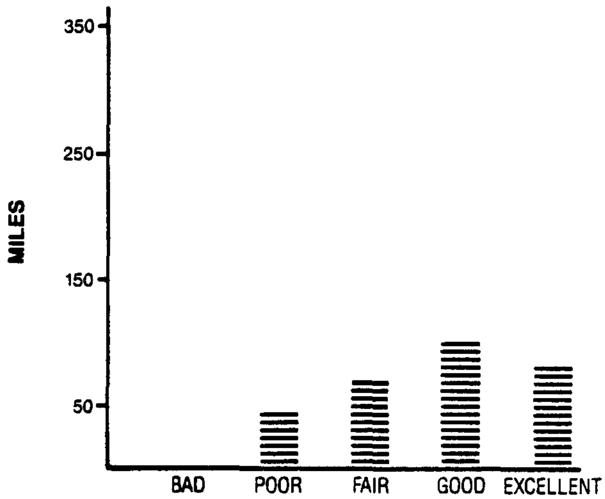
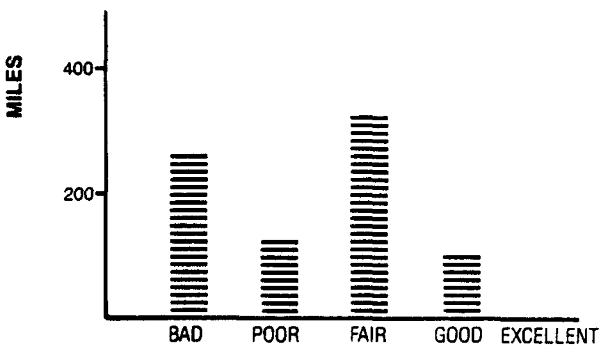


COMMUTER RAIL



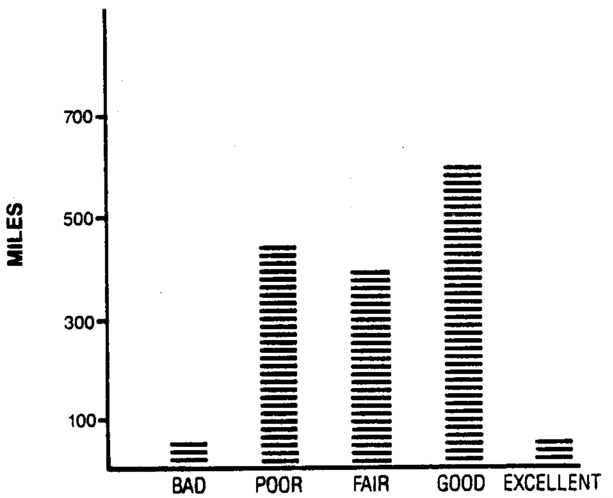
POWER DISTRIBUTION
THIRD RAIL FINDINGS

The inspected transit systems have 1,895 miles of third rail: 73 percent on rapid rail, 1 percent on light rail, and 26 percent on commuter rail. The results of the physical inspection are provided in accompanying condition diagrams.

Of the 1,357 miles of third rail on the rapid transit systems, most is in either "fair" or "good" condition. The light rail systems have only 28 miles of third rail but nearly 24 miles is in "bad" condition. The commuter rail systems have 489 miles of third rail and approximately 54 percent is in "poor" or "bad" condition. All third rail in "bad" condition is over 25 years old and all rail in "poor" condition is more than 35 years old. The third rail in "excellent" condition is all less than 15 years old.

More than 95 percent of the third rail sections are maintained in accordance with some type of formal maintenance program. The only real identified problem is age, with some of the third rail being the older 70 lb/yd type that is planned for replacement with newer and heavier rail. In addition, some third rail heaters and sectionalizing switch replacement is required. In general, these replacements have been made as needed.

RAPID RAIL



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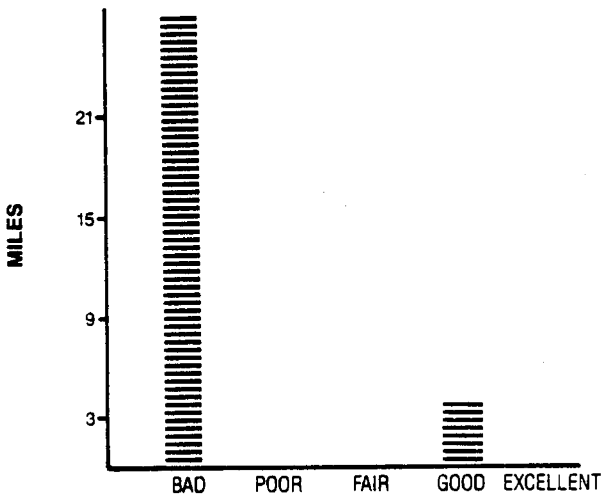

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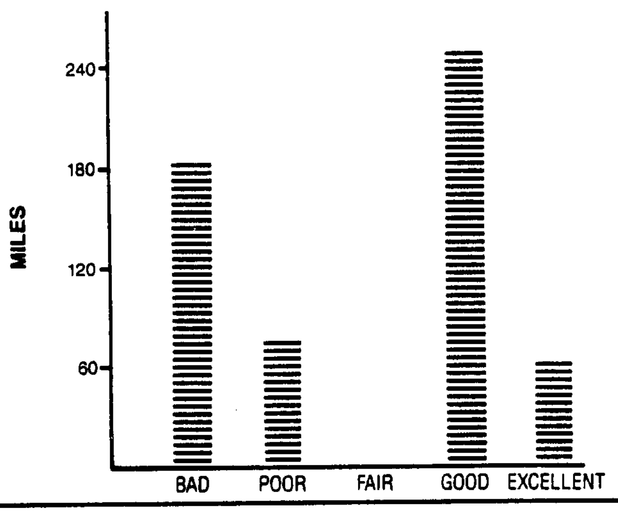
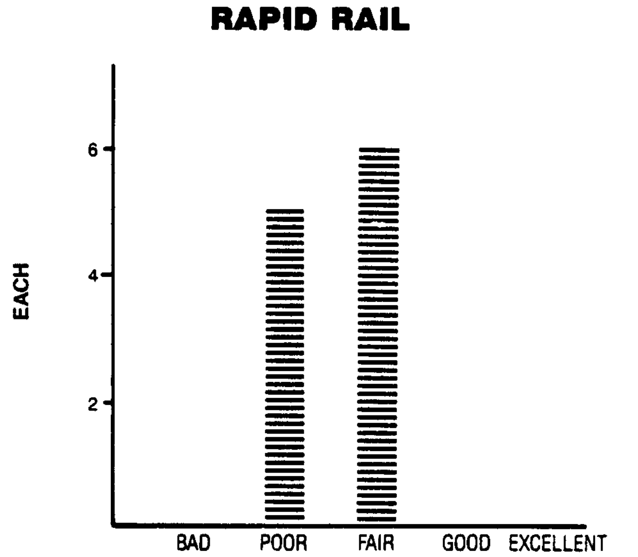


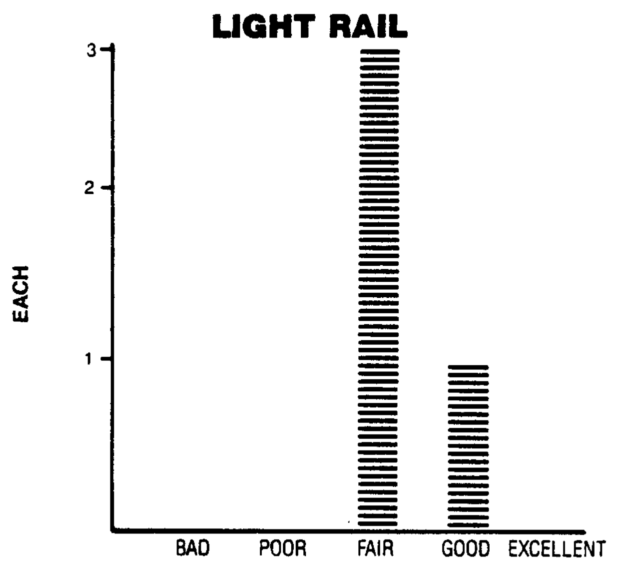
HISTORIC STATION FINDINGS

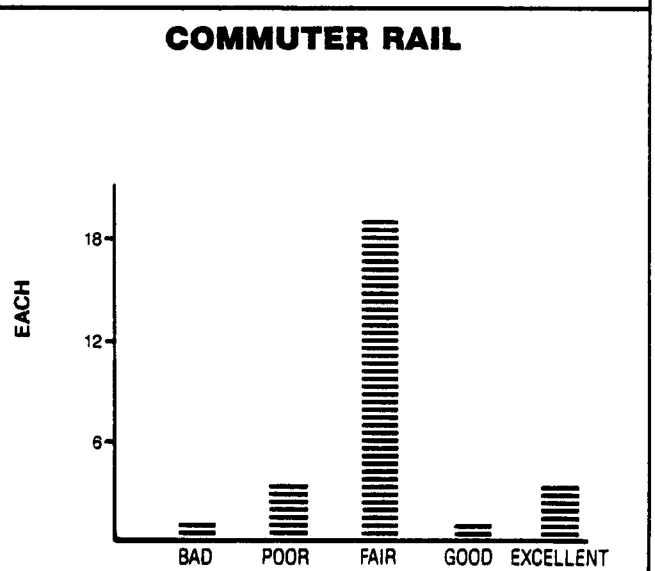
The inspected transit systems have 42 historic stations: 11 on rapid rail systems, 4 on light rail systems and 27 on commuter rail systems. The results of the physical inspections are provided in accompanying condition diagrams.

The historic stations on the rapid rail systems are all in either "poor" or "fair" condition and need to be either rehabilitated or at least refurbished due to age. One of the historic stations on the light rail systems has already been rehabilitated and is in "good" condition; the others are in "fair" condition. Some of the historic stations have also been rehabilitated on the commuter rail systems and four are in either "good" or "excellent" condition; however, most of these stations are only in "fair" condition, as indicated in the diagram.

By definition, most of the historic stations are at least 50 years old and, although generally elaborate and well built, require some structural improvements and equipment replacement. Leaking roofs, no conduits for electrical systems, very old stairs and handrails, deteriorated structure supports and poor drainage systems are some of the identified problems.





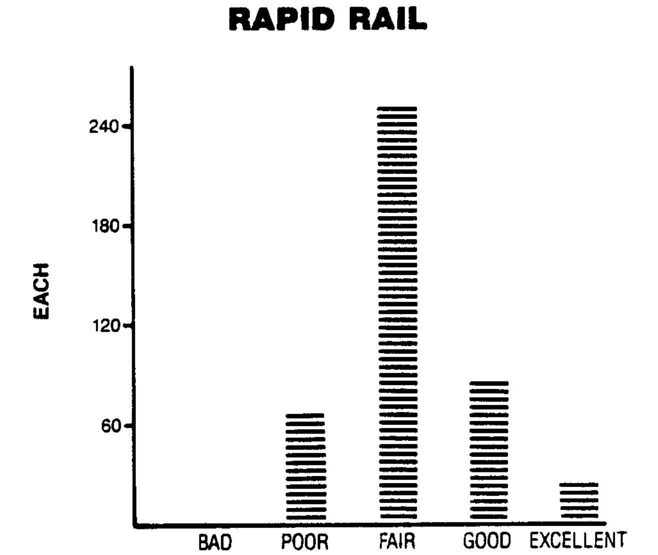


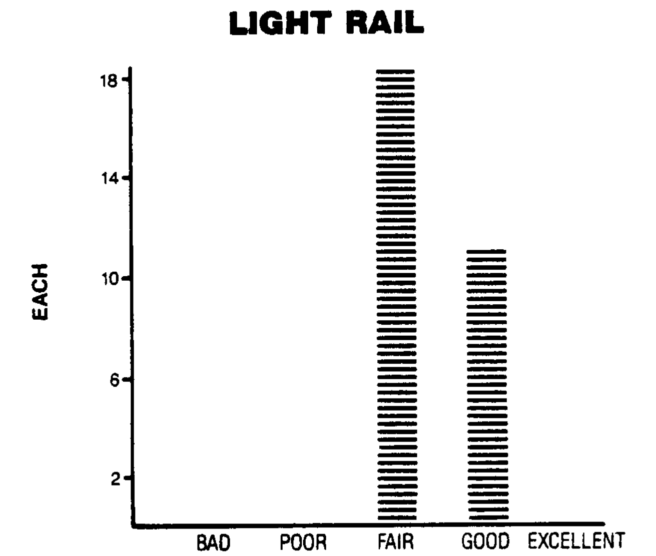
SUBWAY STATION FINDINGS

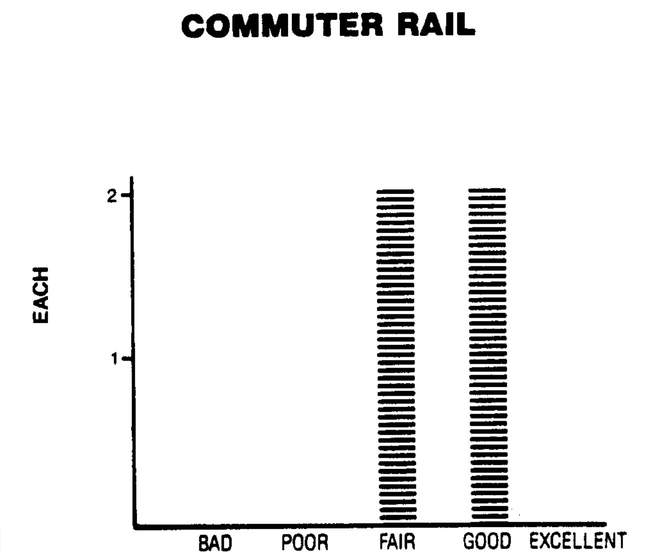
There are 452 subway stations on the inspected transit systems: 93 percent on rapid rail systems, 6 percent on light rail systems and only one percent on commuter rail systems. The results of the physical inspections are provided in accompanying condition diagrams.

The rapid rail systems have 419 subway stations and although more than 60 are estimated as being in "poor" condition, the rest are in "fair" or better condition. The 33 subway stations on light and commuter rail systems are all estimated as being in either "fair" or "good" condition.

The primary reason for the "poor" condition is age, with most of these stations being more than 60 years old. The elevators and escalators on some of these older stations are in "bad" condition or non-operational; wooden platforms need to be replaced; lighting systems are "poor"; graphics should be replaced; and some hairline cracks and spalling were observed in the structures. Vandalism is also a major problem and graffiti is on many station walls and columns.





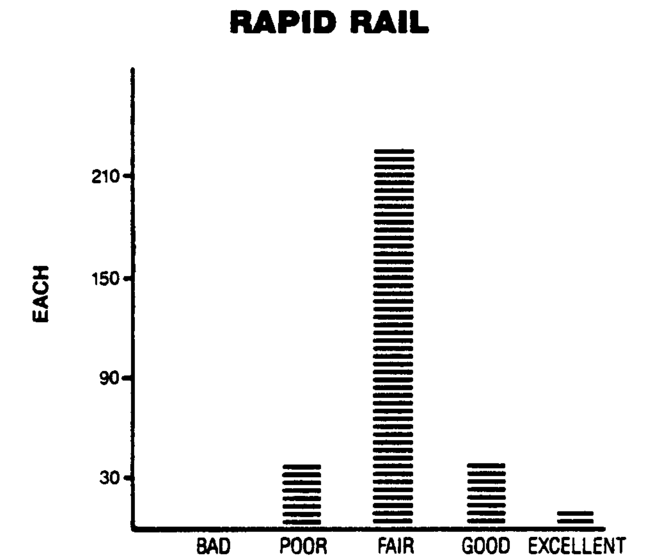


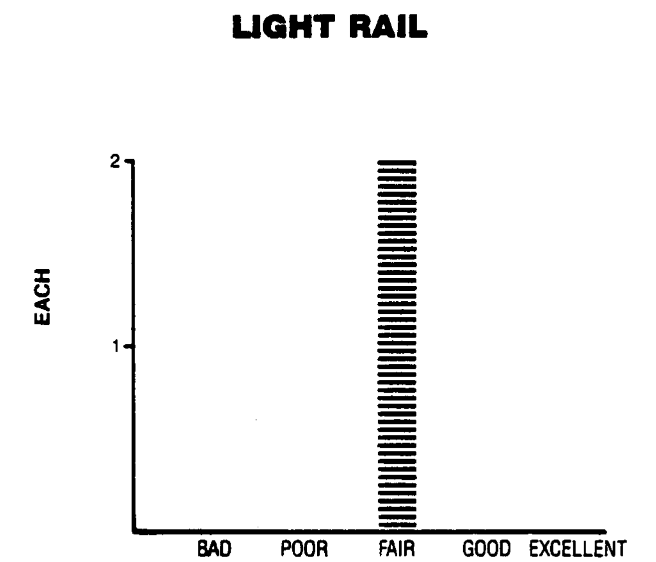
ELEVATED STATION FINDINGS

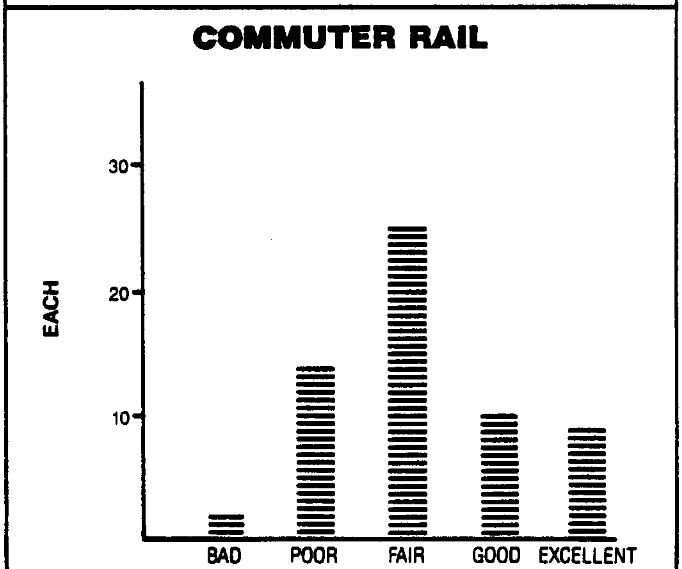
There are 375 elevated stations on the inspected transit systems: 83 percent on rapid rail, one percent on light rail and 16 percent on commuter rail. The results of the physical inspections are provided in accompanying condition diagrams.

Of the 313 elevated stations on rapid rail systems, approximately 13 percent are in "poor" condition, 70 percent are in "fair" condition and the remainder are in "good" or "excellent" condition. Both of the elevated stations on the light rail systems were estimated as being in "fair" condition. The commuter rail systems have 60 elevated stations and 27 percent were estimated as being in "poor" or "bad" condition, 42 percent in "fair" condition and the remaining 31 percent are in either "good" or "excellent" condition.

The primary reason for these stations being in "bad" or "poor" condition is age, with some of them being more than 60 years old. Some of these older stations have leaking roofs, wood members which are rotting, graphics which are poor or nonexistent and mechanical/electrical equipment which should be replaced.







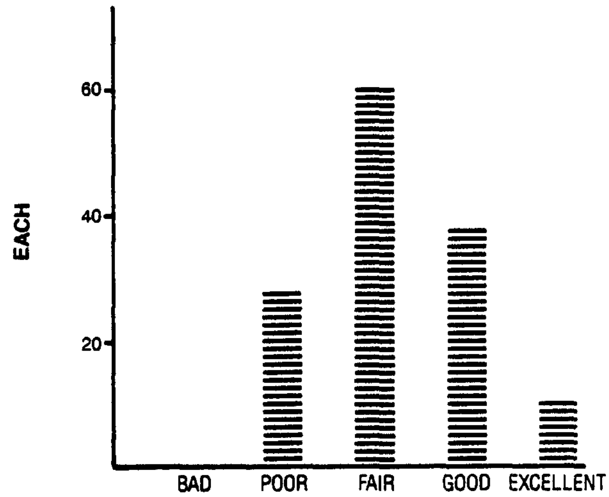
AT-GRADE STATION FINDINGS

There are 713 at-grade stations on the inspected transit systems: 19 percent on rapid rail, 7 percent on light rail, and 74 percent on commuter rail systems. The results of the physical inspections are provided in accompanying condition diagrams.

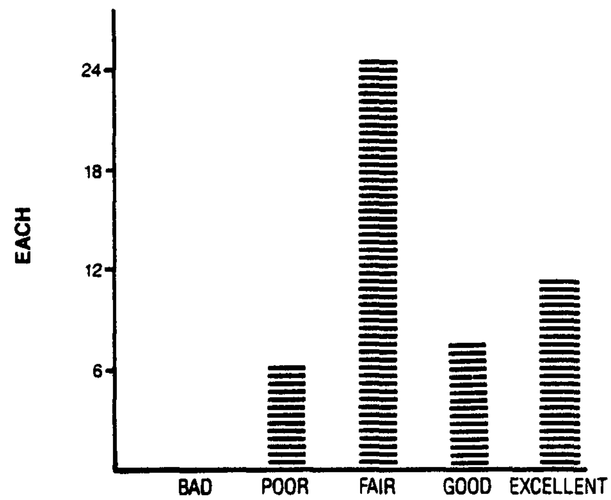
Of the 132 at-grade stations on rapid rail systems, 21 percent are in "poor" condition, 44 percent are in "fair" condition and the remaining 35 percent are in "good" or "excellent" condition. The light rail systems have 51 at-grade stations and 13 percent were estimated as being in "poor" condition, 50 percent are in "fair" condition and the remaining 37 percent are in "excellent" or "good" condition. The commuter rail systems have 530 at-grade stations and about 19 percent are in "poor" condition, 57 percent are in "fair" condition and the remaining 24 percent are in "good" or "excellent" condition.

The primary reason for the "poor" condition is age, with some of these relatively simple at-grade stations being more than 70 years old. Stations structures are sometimes in "poor" to "bad" condition, some platforms have poor circulation and parking is inadequate. Another problem is that most of the stations in "poor" condition have recently been acquired by the transit operators from Conrail and other agencies and only "minimal" maintenance had previously been performed.

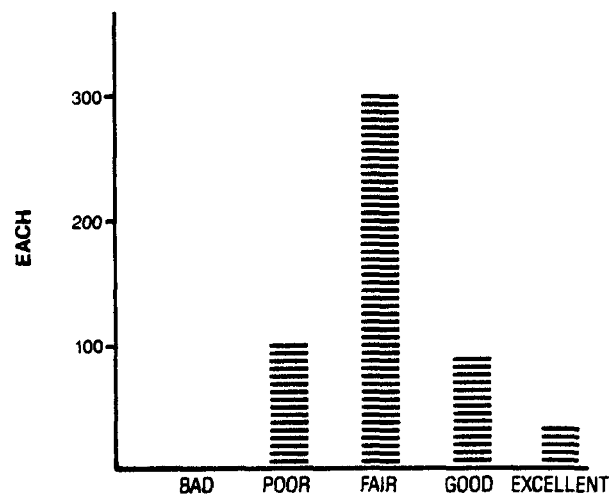
RAPID RAIL



LIGHT RAIL



COMMUTER RAIL



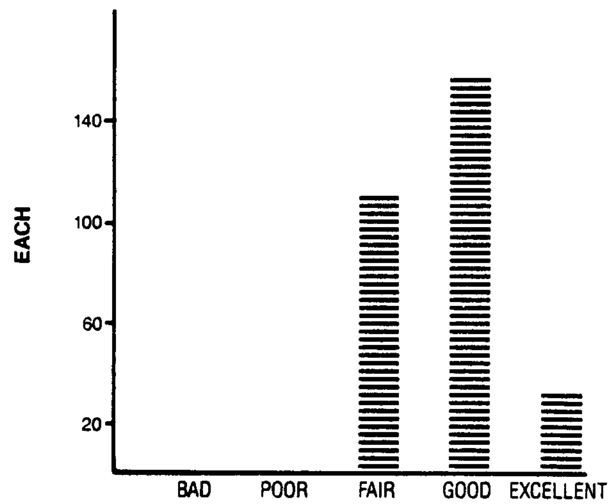
STATION STOP FINDINGS

There are 644 station stops on the inspected transit systems: none on rapid rail, 46 percent on light rail, and 54 percent on commuter rail systems. The results of the physical inspections are provided in accompanying condition diagrams.

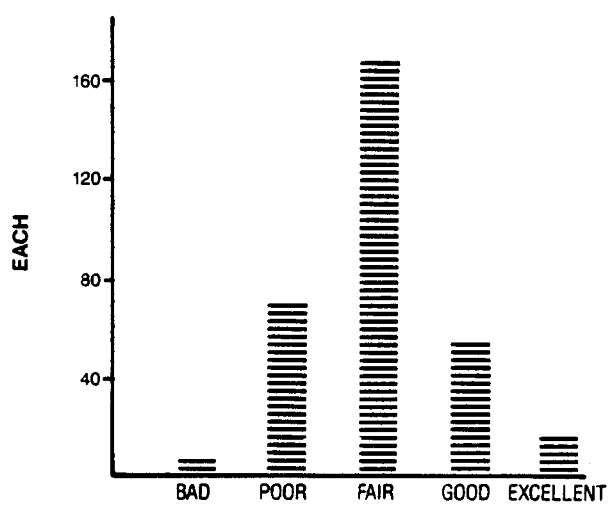
The light rail systems have 294 station stops and 30 percent are in "fair" condition, with the remaining stops in "good" or "excellent" condition. The commuter rail systems have 350 station stops and about 31 percent are in "bad" or "poor" condition, 51 percent are in "fair" condition and the remaining 18 percent are in "good" or "excellent" condition.

RAPID RAIL

LIGHT RAIL



COMMUTER RAIL



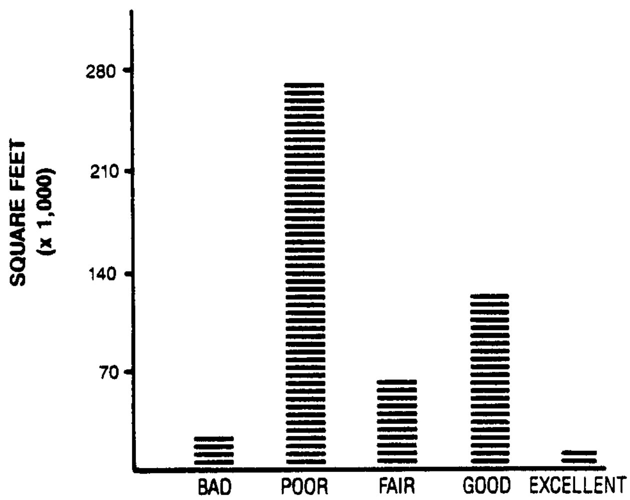
STRUCTURES AND FACILITIES
HIGHWAY BRIDGE FINDINGS
EXCLUDING ELEVATED RAILWAY

There are 2.2 million square feet of highway bridges associated with the inspected transit systems: 23 percent on rapid rail, 5 percent on light rail, and 72 percent on commuter rail systems. The results of the physical inspections are provided in accompanying condition diagrams.

There are 492,240 square feet of highway bridges on the rapid rail systems and about 59 percent of this is in "poor" or "bad" condition, 13 percent is in "fair" condition and the remaining 28 percent is in "good" or "excellent" condition. The light rail systems have 110,090 square feet of highway bridges and 33 percent of this is in "poor" or "bad" condition, 35 percent in "fair" condition and the remaining 32 percent is in "good" or "excellent" condition. The commuter rail systems have 1,583,300 square feet of highway bridges and about 20 percent of this is in "poor" condition, 50 percent is in "fair" condition and the remaining 29 percent is in "good" or "excellent" condition. None of the bridges in "bad" or "poor" condition are less than 50 years old and some are more than 100 years old. The bridges in "excellent" condition are all less than 25 years old and some bridges in "good" condition are over 74 years old.

Typical problems on the older bridges included deteriorated concrete, cracks, corrosion, corrugated metal, and other structural defects. Although most bridges appeared to remain in "fair" condition for at least 60 years, the deterioration appears to be relatively rapid after that age.

RAPID RAIL



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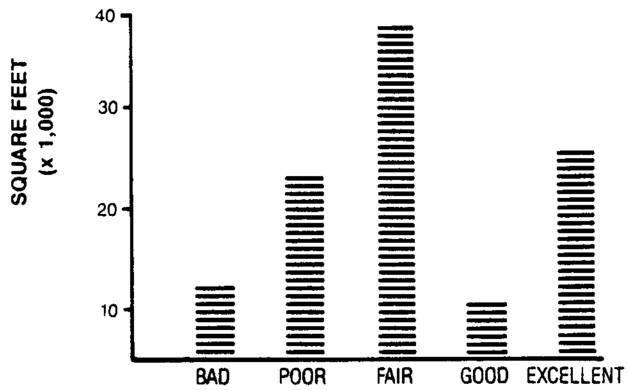

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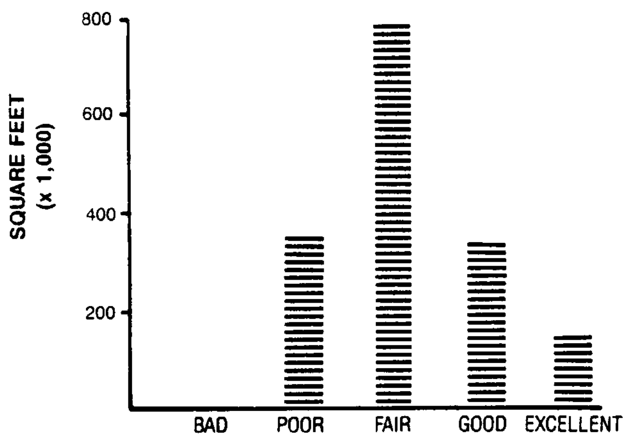


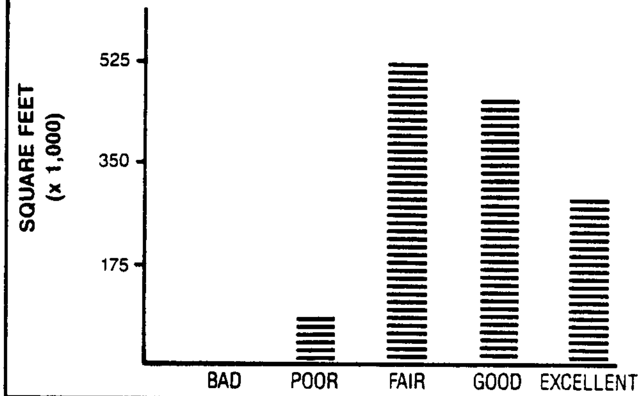
STRUCTURES AND FACILITIES
TRANSIT BRIDGE FINDINGS
EXCLUDING ELEVATED RAILWAY

There are 1.5 million square feet of transit bridges: 88 percent on rapid rail, 12 percent on light rail and none on commuter rail. The results of the physical inspections are provided in accompanying condition diagrams.

The rapid rail systems have 1,340,082 square feet of transit bridges and 6 percent is in "poor" condition, 38 percent is in "fair" condition and the remaining 56 percent is in "good" or "excellent" condition. The light rail systems have 177,574 square feet of transit bridges and 20 percent of this is in "poor" condition, 65 percent is in "fair" condition and the remaining 15 percent is in "good" condition.

The major problems, that were identified, included deteriorated concrete, cracks, corrosion, corrugated metal; most of these problems are associated with the age of the bridges, with some of the "poor" bridges being more than 70. years old.

RAPID RAIL



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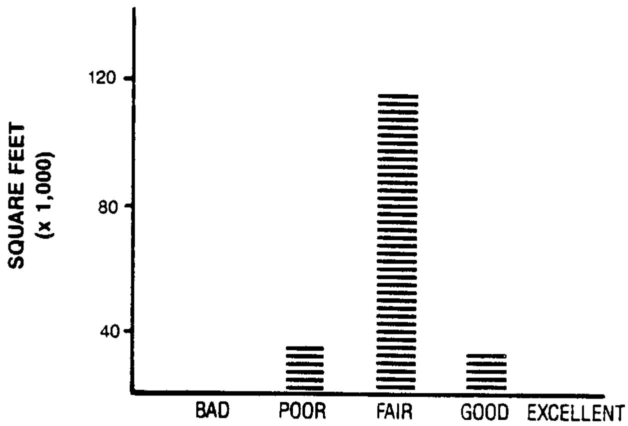


COMMUTER RAIL

STRUCTURES AND FACILITIES
RAILWAY BRIDGE FINDINGS
EXCLUDING ELEVATED RAILWAY

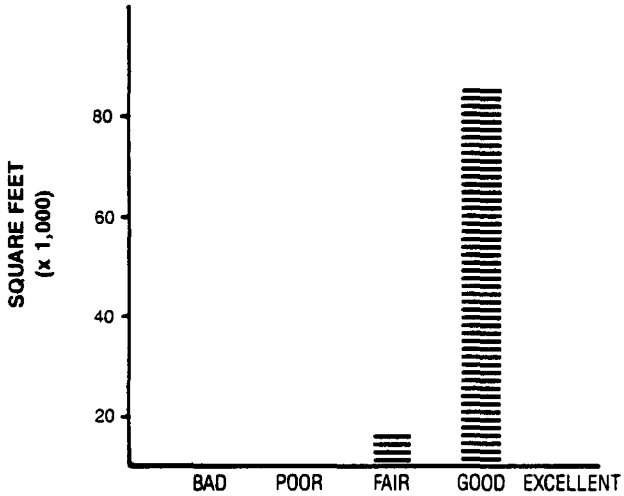
There are 7.65 million square feet of railway bridges on the inspected transit systems: 1 percent on light rail systems and 99 percent on commuter rail systems. The results of the physical inspections are provided in accompanying condition diagrams.

The light rail systems contain 91,480 square feet of railway bridges and 1,500 square feet is in "fair" condition and the remaining 89,980 square feet is in "good" condition. Of the 7,560,167 square feet of railway bridges on commuter rail systems, approximately 14 percent is in "poor" condition, 56 percent is in "fair" condition and the remaining 30 percent is in "good" or "excellent" condition.

The primary reason for the "poor" condition is age, with some of these bridges being 75 to 100 years old and having some structural problems. Corrosion due to salt spray and spalling of concrete, exposed rebar, and mortar and stone deterioration are evident on some of these older bridges. A general policy of "minimal" maintenance on all bridges has resulted in the deterioration to a "bad" or "poor" condition for bridges that are over 50 years old.

RAPID RAIL

LIGHT RAIL



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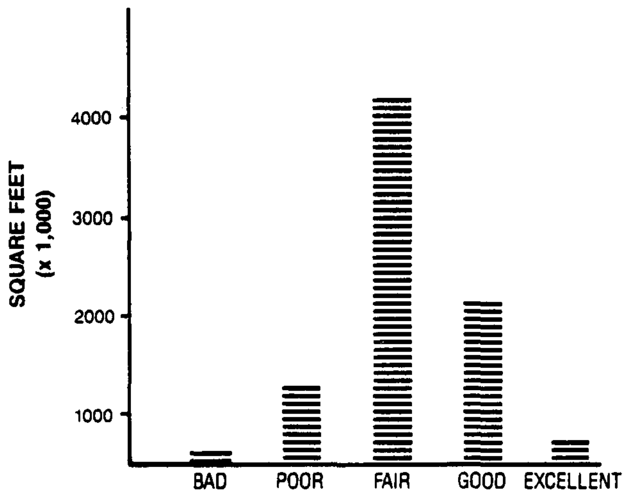
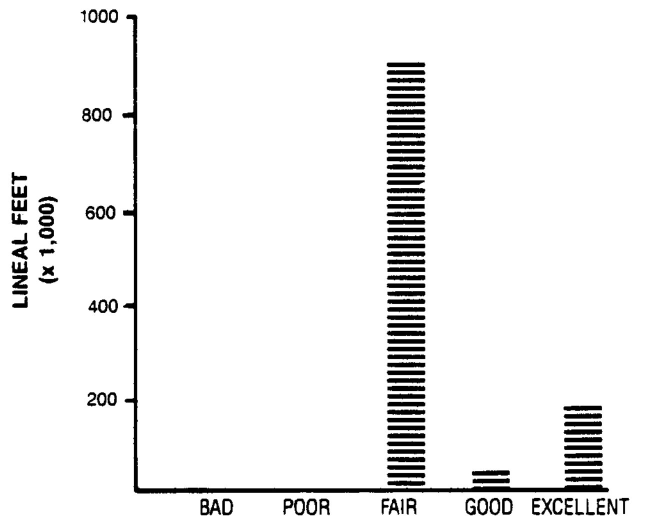


STRUCTURES AND FACILITIES
ELEVATED RAILWAY BRIDGE FINDINGS

There are 1.2 million lineal feet of elevated railway bridges associated with the inspected transit systems: 92 percent on rapid rail, less than 1 percent on light rail, and 8 percent on commuter rail. The results of the physical inspections are provided in the accompanying condition diagrams.

Of the 1,077,325 lineal feet of elevated railway bridges on the rapid rail systems, 83 percent is in "fair" condition, 1 percent is in "good" condition, and the remaining 16 percent is in "excellent" condition. The light rail systems have 5,180 lineal feet of elevated railway bridges and 68 percent is in "poor" condition, 15 percent is in "fair" condition, and the remaining 17 percent is in "good" condition. The commuter rail systems have 92,120 lineal feet of elevated railway bridges and about 8 percent is in "poor" or "bad" condition, 48 percent is in "fair" condition, and 44 percent is in "good" or "excellent" condition.

RAPID RAIL



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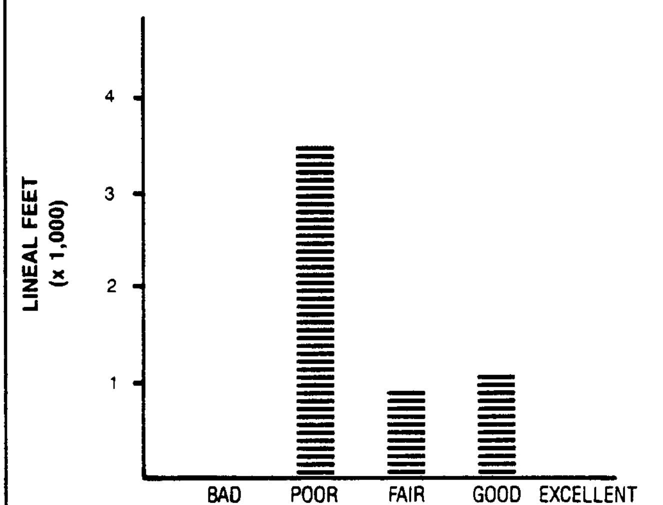

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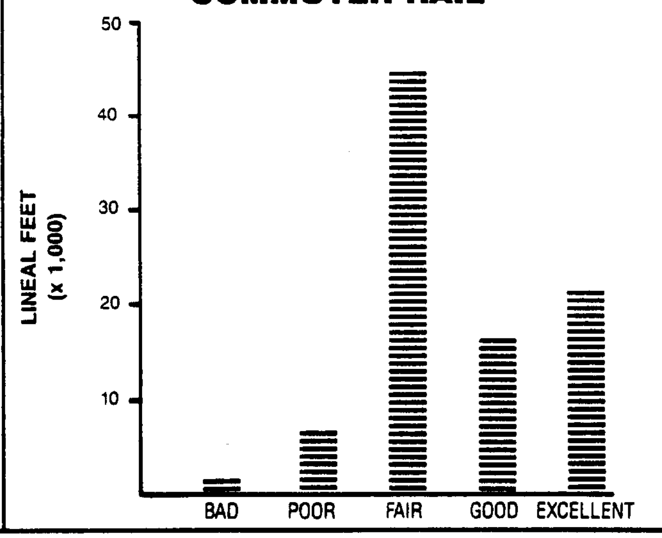
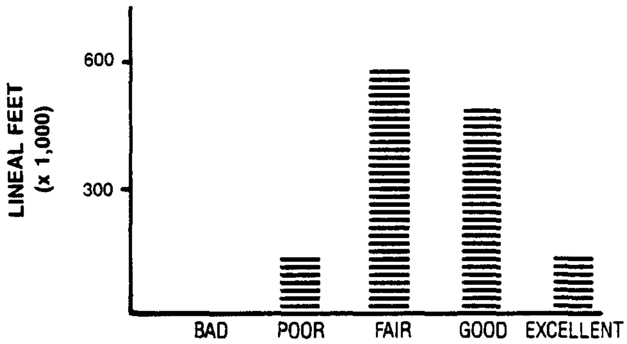


STRUCTURES AND FACILITIES
TUNNEL FINDINGS

There are 1.6 million lineal feet of tunnels associated with the inspected transit systems: 92 percent on rapid rail, 4 percent on light rail, and 4. percent on commuter rail systems. The results of the physical inspections are provided in accompanying condition diagrams.

Of the 1.5 million lineal feet of tunnels on rapid rail systems, 4 percent is in "poor" condition, 47 percent is in "fair" condition and the remaining 49 percent is in "good" or "excellent" condition. The light rail systems have 57,900 lineal feet of tunnels and 3 percent is in "poor" or "bad" condition, 44 percent is in "fair" condition and the remaining 53 percent is in "good" condition. The commuter rail systems have 66,876 lineal feet of tunnels,and 37 percent is in "poor" condition, 60 percent is in "fair" condition and the remaining 4 percent is in "good" condition. All of the tunnels in "bad" condition are over 75 years old and those in "poor" condition are over 35 years old. Most tunnels in "excellent" condition were less than 20 years old, however some tunnels in "excellent" condition were between 35 and 60 years old. In addition, there were no tunnels that were in "poor" condition that were less than 35 years old. There were also some tunnels in "good" condition that were over 75 years old.

RAPID RAIL



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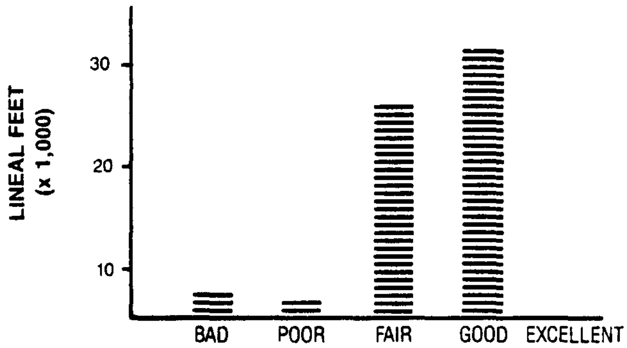
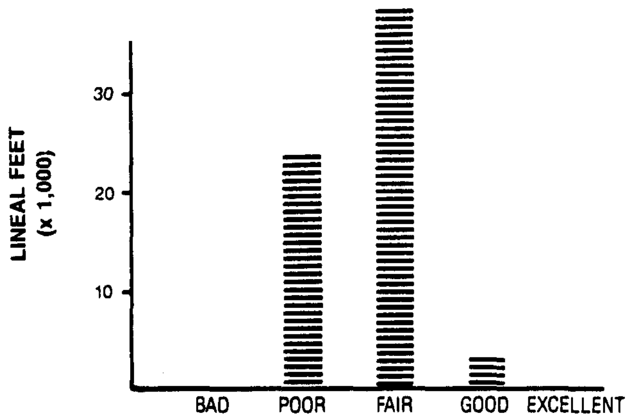


COMMUTER RAIL

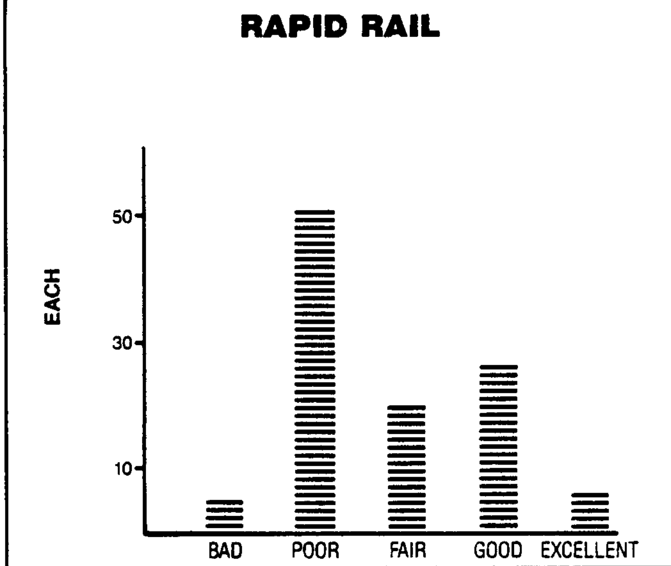


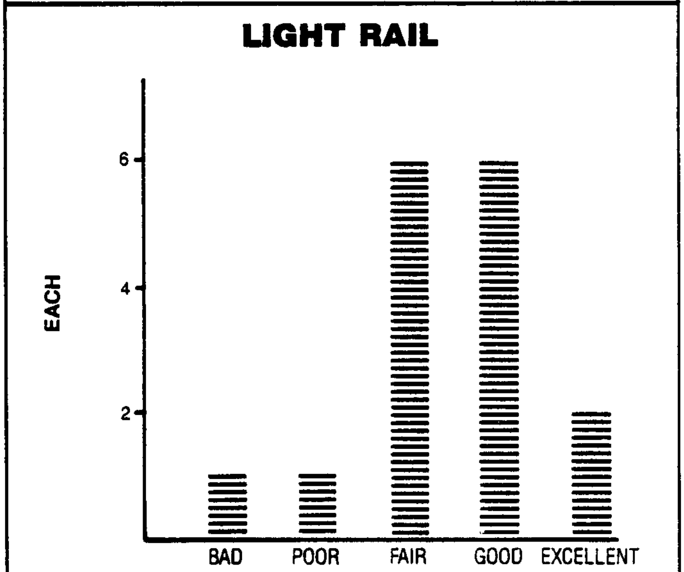
MAINTENANCE BUILDING FINDINGS

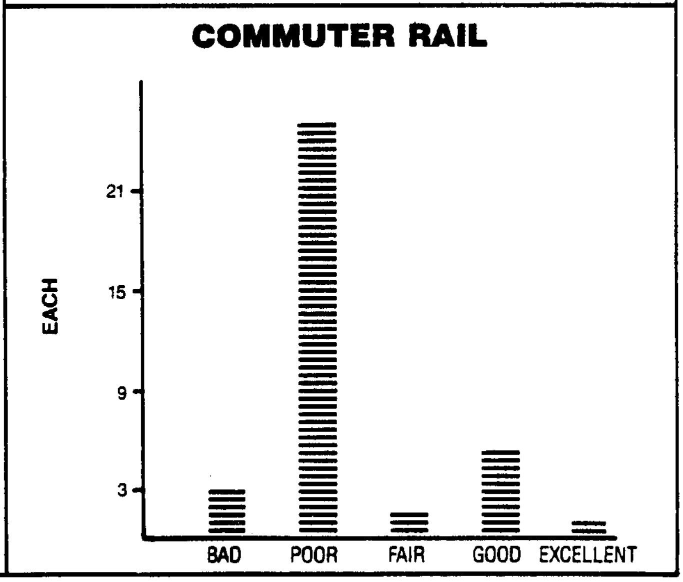
There are 153 maintenance facility buildings on the inspected transit systems: 67 percent on rapid rail, 10 percent on light rail, and 23 percent on commuter rail systems. The results of the physical inspection are provided in accompanying condition diagrams.

Of the 102 maintenance buildings on rapid rail systems, 53 percent are in "poor" or "bad" condition, 17 percent in "fair" condition and the remaining 30 percent are in "good" or "excellent" condition. The light rail systems have 16 buildings and about 13 percent are in "poor" or "bad" condition, 38 percent in "fair" condition and the remaining 49 percent are in "good" or "excellent" condition. The commuter rail systems have 35 maintenance facility buildings and about 83 percent are in "poor" or "bad" condition, 6 percent are in "fair" condition and the remaining 11 percent are in "good" or "excellent" condition. All of the maintenance facility buildings in "bad" condition are more than 25 years old and most of the buildings in "poor" condition are 25 to 40 years old. The buildings in "excellent" condition were all less than 15 years old. In addition, some of these buildings had deteriorated to "poor" or "fair" condition in less than 15 years and some buildings were still in "good" condition that were more than 35 years old.

A possible reason for the range of conditions for different age groups is that a policy of "minimal" maintenance on the buildings is usually performed, resulting in relatively rapid deterioration; the buildings are then rehabilitated back to a "good" condition.







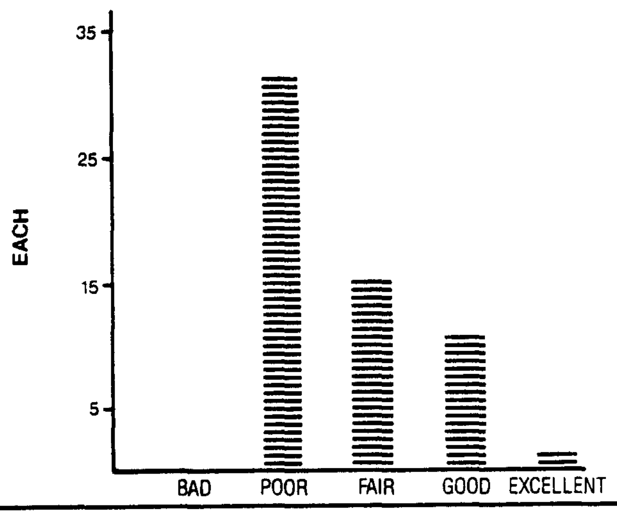
MAINTENANCE/STORAGE YARD FINDINGS

There are 132 maintenance and storage yards on the inspected transit systems: 45 percent on rapid rail, 9 percent on commuter rail, and 46 percent on light rail systems. The results of the physical inspections are provided in accompanying condition diagrams.

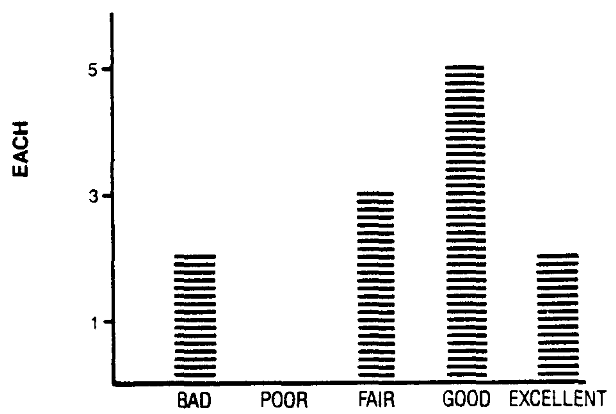
Of the 59 maintenance yards on rapid rail systems, 54 percent are in "poor" condition, 26 percent are in "fair" condition, and the remaining 20 percent are in "good" or "excellent" condition. The light rail systems have only 12 yards and 2 are in "poor" condition, 3 are in "fair" condition and the remaining 7 are in "good" or "excellent" condition. The commuter rail systems have 61 maintenance/storage yards and and about 46 percent are in "poor" or "bad" condition, 48 percent are in "fair" condition and the remaining 6 percent are in "good" or "excellent" condition. All of the yards in "bad" condition are more than 25 years old, but some yards are in "poor" condition that are less than 15 years old. In addition, some yards are in "good" condition that are more than 35 years old. The only yards in "excellent" condition are less than 15 years old.

A possible reason for the apparent early deterioration is a general policy of "minimal" maintenance and then rehabilitation back to a "good" condition after 25 years of operation.

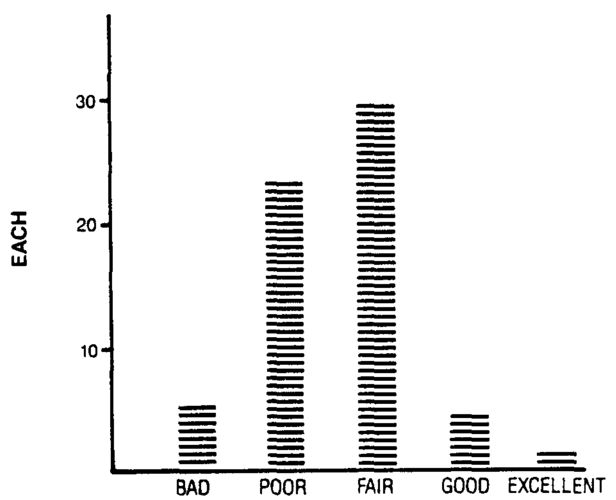
RAPID RAIL



LIGHT RAIL



COMMUTER RAIL



3.3 SUMMARY OF CONDITION BY TYPE OF TRANSIT SYSTEM FOR EACH MAJOR RAIL AREA

The primary purpose of this section is to provide a summary of the results of the physical assessments for each major rail area. For this presentation of the results, the inspected transit systems have been consolidated, as indicated in Table 3.3.

TABLE 3.3

Rail Modernization Area Designations

Major Rail Areas	Type of Transit System	Transit System
Boston	Rapid Rail	MBTA
	Light Rail	MBTA
	Commuter Rail	MBTA
New York	Rapid Rail	NYCTA, SIRTOA
	Commuter Rail	LIRR, Metro-North
Northern New Jersey	Rapid Rail	PATH
	Light Rail	NJTC
	Commuter Rail	NJTC
Southern New Jersey	Rapid Rail	PATCO
Philadelphia	Rapid Rail	SEPTA
	Light Rail	SEPTA
	Commuter Rail	SEPTA
Pittsburgh	Light Rail	PAAC
	Commuter Rail	PAAC
Chicago	Rapid Rail	CTA
	Commuter Rail	RTA (BN, C&NW, ICG, RI, MR, N&W, NICTD)
Cleveland	Rapid Rail	GCRTA
	Light Rail	GCRTA
San Francisco	Rapid Rail	BART
	Light Rail	MUNI
	Commuter Rail	CALTRANS San Francisco
Washington, DC	Rapid Rail	WMATA
	Commuter Rail	Maryland DOT
Atlanta	Rapid Rail	MARTA
New Orleans	Light Rail	RTA New Orleans
San Diego	Light Rail	MTDB

The following sections provide the results of the evaluation of the conditions of the system elements/major subsystems by type of transit system for each of the designated major rail areas.

- Track Condition

  The condition of the track is provided in Table 3.4. The rapid rail systems have 158 miles of "poor" track and 762 miles of "fair" track, with most of this track being in New York City (643 miles). The light rail systems have 135 miles of "poor" track and 109 miles of "fair" track, with most of this track being in Philadelphia, Pittsburgh, and San Diego (201 miles). The commuter rail systems have 17 miles of "bad" track (all in Boston), 55 miles of "poor" track (52 miles in Boston), and 1,646 miles of "fair" track (48 percent in Chicago).

  A discussion of the track condition in each of the major rail areas follows, with some emphasis on items of particular concern:

  - BOSTON

    The rapid rail track includes some 115 lb/yd RE continuous welded rail, which is in good to excellent

TABLE 3.4

TRACK CONDITION (Miles)

Major Rail Areas	Rapid Rail						Light Rail						Commuter Rail					
	E	G	F	P	B	T	E	G	F	P	B	T	E	G	F	P	B	T
Boston	7	48	-	28	-	83	21	19	-	15	-	55	23	11	240	52	17	343
New York	-	46	540	103	-	689						NA	259	795	82	-	-	1136
Northern NJ	-	-	29	-	-	29	-	-	9	-	-	9	23	143	315	-	-	481
Southern NJ	-	26	3	-	-	29						NA						NA
Philadelphia	1	6	50	-	-	57	4	-	29	120	-	153	23	2	213	-	-	238
Pittsburgh						NA	-	21	24	-	-	45	-	57	-	-	-	57
Washington, DC	98	-	-	-	-	98						NA						NA
Chicago	-	86	137	-	-	223						NA	-	249	796	3	-	1048
Cleveland	-	9	3	27	-	39	-	20	-	-	-	20						NA
Atlanta	10	25	-	-	-	35						NA						NA
New Orleans						NA	-	-	14	-	-	14						NA
San Francisco	119	29	-	-	-	148	36	-	5	-	-	41						NA
San Diego						NA	4	-	28	-	-	32						NA
TOTAL	235	275	762	158	0	1430	65	60	109	135	0	369	328	1257	1646	55	17	3303

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

NA - Not Applicable

condition. But the 85 lb/yd ASCE and 100 lb/yd ARA-B rails are only in "fair" to "poor" condition. All rail sections exhibit corrugations. The bolted rail joints are in "fair" condition. Some field welds have broken in cold weather. The cut and screw spike fasteners are in "fair" condition. Direct fixation

Badly Fouled Ballast in Subway Track

fasteners present some major problems but the spring clip fasteners are in "excellent" condition. The ballast is fouled and should be replaced in the subways. In the bolted rail sections, the turnouts and crossovers are in "poor" condition; worn switch points, battered frogs, and worn closure rails are the main problems.

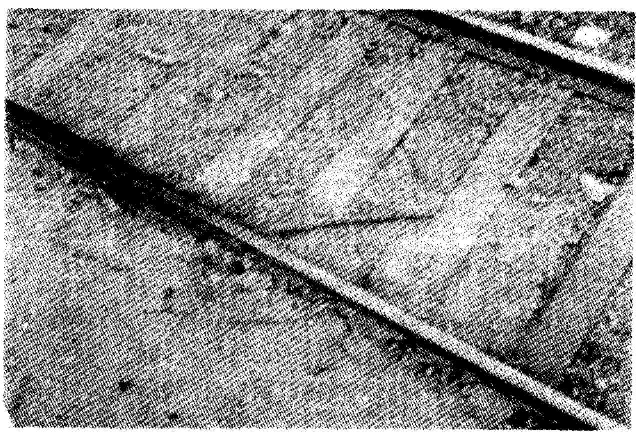
The light rail system also includes some 115 lb/yd RE CW rail, which is in "good" to "excellent" condition. However, the 85 lb/yd ASCE and 100 lb/yd ARA-B rail is only in "fair" to "poor" condition; rail head surface defects are most noticeable at the rail joints. The conventional rail fasteners on the timber ties are in "fair" condition. The anchoring pattern is sporadic or almost nonexistent but fasteners and anchors on welded rail segments are "good". The direct fixation systems have problems with shims and grouted anchor bolts but the spring clip fasteners on the timber ties are in "excellent" condition.

The ballast is in "poor" condition on the subways and on the ballast deck bridges. Some worn switch points, battered and worn frogs and worn closure rails on some bolted rail segments make these segments "poor" to "fair". In addition, some subway and elevated track have "fair" to "poor" alignment and surface. The subway drainage is "poor" and the ballast is contaminated.

The track on the commuter rail system is mostly in "bad" to "fair" condition; the rail exhibits end batter, corrugation, rail head defects, and heavy wear on the gauge side on the outside rail on the curves. Generally, the bolted rail joints are in "fair" condition, but many standard insulated joints would have to be replaced. Rail fasteners are generally in "good" condition but anchors are sporadic or nonexistent on some bolted rail sections. While most of the ballast is in generally "good" condition, some pumping and fouled ballast was observed and many areas require additional ballast. There are many areas where new or relaid rail has been installed but turnouts or crossovers were not replaced. The drainage is poorest at the stations and grade crossings and fouled and pumped ballast was observed.

- NEW YORK

The track condition on the rapid rail systems was estimated to be mostly "fair" and "poor", but the rail itself was judged to be "poor" on over 240 track miles and in "fair" condition on more than 520 track miles. The conventional cut spike fastening system was also rated to be generally "fair" over most of the system. But the sawn timber ties were judged to be in generally "poor" condition. Most ballast, where it exists, is in generally "fair" to "poor" condition and is fouled to the point where drainage is becoming a serious problem, particularly in the ballasted tunnel segments. Switches were judged to be in either "poor" or only "fair" condition; besides being heavily worn, many switches are of the obsolete knuckle-and-lap type rather then the American Railway Engineering Association (AREA) standard switch. The drainage was judged to be in "poor" to "fair" condition over most track segments in the tunnel and at-grade. Fouled ballast within the tunnel portions of the system has resulted in many clogged drains and has created drainage problems. At-grade ditches were also found to be clogged and silted in a number of areas.



Fouled Ballast and Mud

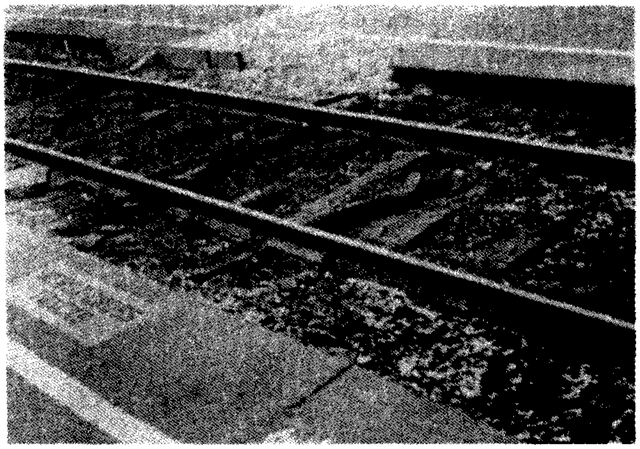
The commuter rail track is generally in "good" to "excellent" condition, with the installation of welded rail and thousands of new ties over the entire system. The welded rail, which has already been installed, is in "good" to "excellent" condition. The conventional fastening and anchoring system is in generally "fair" condition and the newly installed direct fixation and spring clip rail fastening and anchoring systems are in "good" to "excellent" condition. However, many poorly drained and fouled ballast areas exist at the bridge and crossing approaches.

- NORTHERN NEW JERSEY

The rapid rail track is in "fair" condition; however, the rail over the entire system is in generally "good" condition except for some 85 lb/yd rail. This rail has an average age of 52 years and is in "poor" to "fair" condition. The rail joints are in generally "good" condition except for the "poor" to "fair" joints in the 85 lb/yd rail section on the Uptown Branch. The direct fixation fastening system in the station areas is in "fair" condition. Except for signs of corrosion on some of the tunnels, the conventional spike and anchoring system is in generally "good" condition. The crossties are in overall "fair" condition. In some areas, the fouled ballast is retaining water, causing more rapid deterioration of the ties. The ballast on most of the track is in "fair" condition, except for the portion on the Uptown Branch where it is fouled and in "poor" condition. Turnouts, switches, and other special trackwork and machinery are in generally "fair" condition throughout the system. The greatest problem with alignment and gauge are the sharp curves within the subway system. Otherwise, the alignment and gauge are in generally "good" condition. Most of the route length provides an adequate width for roadbed with stable shoulders and slopes.

The light rail track is in mostly "fair" condition with the existing 100 lb/yd rail being replaced with new 150 lb/yd AREA rail. Rail joints are in "poor" or "fair" condition and are currently being either eliminated or replaced with new adhesive-type insulated joints. The sawn timber ties are in "poor" or only "fair" condition and are presently scheduled for replacement. Existing ballast is heavily fouled and additional new ballast should be added to raise the track. Much of the roadbed, embankment, and cut slopes have been eroded. Dense vegetation has also overgrown portions of the at-grade roadway. A large part of the roadbed, particularly in open cut areas, is poorly drained. Ditching work has been scheduled and should help alleviate the current drainage problems. Fencing is in generally "poor" condition but is scheduled to be replaced with new eight-foot chain-link fencing.

The track on the commuter rail line is in generally "fair" condition with some exceptions, which are in "good" or "excellent" condition.

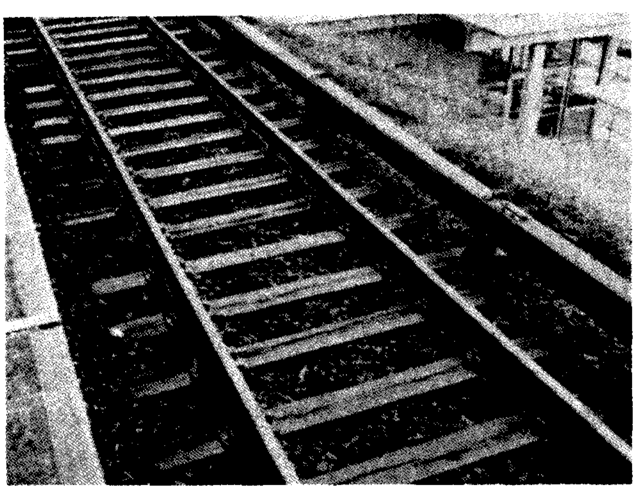


Loose Spikes and Deteriorated Ties

Rail joints on the system are generally in "fair" condition. Ballast and subballast and the special trackwork and machinery are also in generally "good" condition with the exception of the Princeton Line which is in "poor" condition. The alignment, gauge, and surface are in "fair" to "excellent" condition. Drainage on the Montclair Branch is in "poor" condition but on most of the other rail lines, the drainage is "good". The grade crossings are also in "fair" condition but some were recently rebuilt and these grade crossings are in "excellent" condition.

- SOUTHERN NEW JERSEY

The rapid rail track is in mostly "good" condition, with the heaviest wear and deterioration of the rail on the bridge slopes and subway curves. The rail joints are in "excellent" condition and the bolt tightening and replacement program prevents rail batter and weak joints. The rail fasteners are well maintained and the condition is "good". There is some deterioration of the crossties and a limited replacement program would be needed to keep the crossties in "good" condition. The ballast is in "good" condition and there is very little fouling. The rail heaters must be turned on manually; the lubricators do not lubricate evenly. The track alignment, gauge, and surface are in "good" condition; tamping and rail grinding machines are used to maintain a smooth rail head and a good track surface. There are some isolated drainage problems but no ballast fouling or pumping was observed. Most of the problems with the fencing were due to erosion.



Bolted Compression Clip With Tie Plate Lock Spike

- PHILADELPHIA

The rapid rail track is in generally "fair" to "good" condition but some of the bolted rail is in "fair" to "poor" condition. Insulated joints and standard joints within the bolted track sections are in generally "good" condition but have high maintenance requirements. The standard rail fastening systems in the tie block and tie and ballast track are in "fair" condition but some of the embedded ties on the aerial structures are in "poor" condition as is the concrete around the ties. The special trackwork units are in "fair" condition, with many units requiring full or partial replacement. Overall, the track drainage throughout the system is in "good" condition. However, within the tunnel, standing water was observed in some locations and the drainage should be cleaned to allow water runoff to drain freely.

The track on the light rail system was mostly in "poor" condition. Continuously welded tee rail is in generally "good" condition but has significant wear on tight radius curves. The bolted tee rail is in "fair" to "poor" condition. The rail joints on the bolted rail are in "fair" condition, but within the paved streets, the pavement is breaking up at many rail joint locations. The cut and spike and tie plate fasteners used throughout the system are in "fair" to "poor" condition with rail anchoring being sporadic or nonexistent. Some of the special trackwork within the tunnels exhibits rail wear due to heavy traffic. Worn switch points, battered and worn frogs, and worn curb closure rails are the main problems. The surface of the track within the paved streets has settled in many locations.

Badly Damaged Girder Rail Along Embedded Track

The commuter rail track is in "fair" condition but most of the rail is in "poor" condition, with only some sections rated as being in "fair" condition. A large number of rail joints were judged to be in overall "fair" condition and as bolted rail is replaced with continuous welded rail, the problem of troublesome joints will be alleviated. The existing crushed stone ballast and cinder subballast is in "fair" condition, except for a number of localized areas that are excessively fouled.

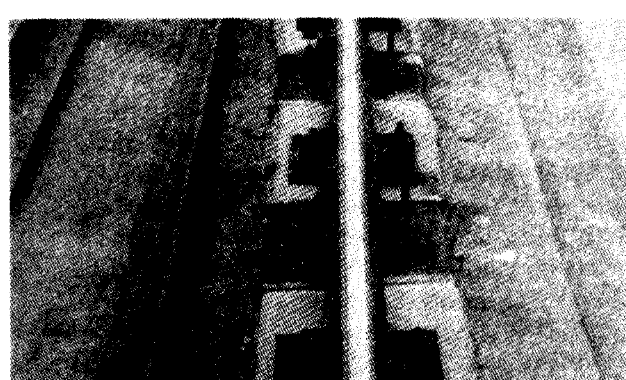
- PITTSBURGH

The light rail track condition is mostly "fair" to "good" but the average age of the rail exceeds 35 years; several portions show severe rail head wear. Insulated and bolted rail joints are generally in "fair" condition but some loose joints have corrosion and surfacing problems. The cut spike system is generally in "poor" to "fair" condition but missing, discarded and unused fasteners were noted. Most sawn timber crossties are in "poor" and "fair" condition. The crushed stone and crushed slag is mostly in "poor" condition and was fouling and deteriorating. The drainage is in overall "good" condition, but some ditch cleaning and reshaping is desirable.

The commuter rail track is mostly in "good" condition, including the rail, rail joints, rail fastening and anchor systems, and the crossties. The crushed stone and slag ballast over most of the main line remains in "good" condition with only isolated cases of fouling.

- WASHINGTON, DC

The rapid rail track is in "excellent" condition but the direct fixation systems on all elevated structures and tunnels have provided some problems.



Direct Fixation Fasteners

The conventional cut spike fastening and anchor system used in the open areas is in "excellent" condition. Additional ballast is being added, as required, and is in very good condition. There are some minor problems with the switch points wearing out, especially on the sharp curves.

The track on the commuter rail system was not inspected since it is not maintained by the Maryland Department of Transportation.

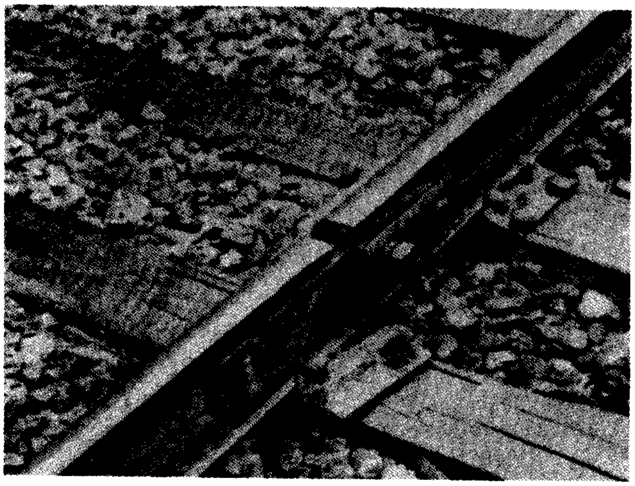
- CHICAGO

The rapid rail track is mostly in "fair" to "good" condition but the rail is only "fair" and some portions should be replaced. Rail joints are in "good" condition and continuous welded rail should be used during the replacement program. The fasteners and anchor systems are "good" but some areas would need reconditioning. The ballast and subballast is "poor" to "good" with some segments having deteriorated and fouled ballast/subballast, which should be replaced when the concrete ties are replaced with timber ties. Some of the track is out of alignment but the track surface is in generally "good" condition.

The commuter rail track is in generally "fair" to "good" condition but several areas of worn or lightweight rail occurs throughout the system. Some line segments have areas with more then the desirable number of deteriorated and split ties. Some line segments also have areas of fouled and deteriorated ballast which should be undercut, cleaned and replaced as necessary. Some of the continuous welded rail, which was installed only 6 to 7 years ago, already has a corrugated riding surface. Although the drainage is "good" on most the mainline track, some ballast deterioration and settling has resulted in poor drainage on some sections of the track.

- CLEVELAND

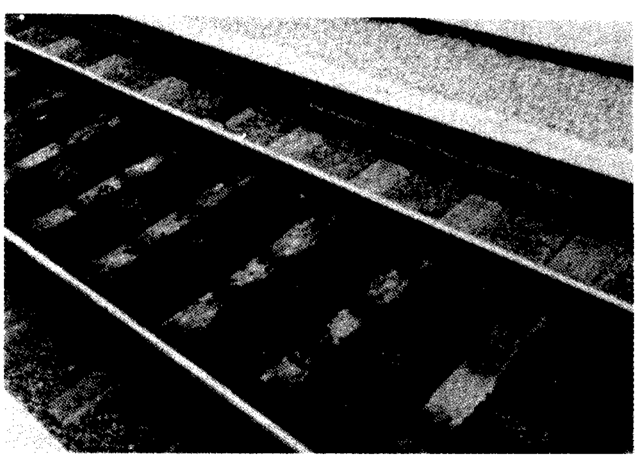
The rapid rail track was observed to be in mostly "poor" condition with signs of heavy rail wear, particularly along the curves. Field welds are in "good" condition but the rail surface is pitted near the field welds and the insulated joints are a problem. No rotted or crushed ties were observed but many ties are damaged by splitting. Ballast on all lines was in "good" condition, but some fouling has occurred on these lines. The track on the light rail system is in "good" condition, with no major problems.



Badly Insulated Joints

- ATLANTA

The rapid rail track condition is mostly "good" or "excellent". The only problem areas are on some of the sharper curves where some flange wear was noted on the rails themselves. Installation of rail lubricators has lessened the wear rate significantly. Some problems exist with the direct fixation fastening system on the sharp curves; the metal anchorage embedded in the concrete is weakening, resulting in the rail clips falling out. The spring clip fasteners on the concrete ties are performing very well. Turnouts and crossovers are in generally "good" condition, although the rail clips must be continuously tightened, particularly in the frog areas. The gauge problems are primarily in curves, where the fasteners are defective and the rail wear is significant. Although drainage is "good" throughout the system, some ponding of water was evident on the viaducts and in tunnels. In some tunnel sections, grooves are being cut in the concrete to keep the water away from the fasteners.



Spring Clip Fasteners on Concrete Ties

- NEW ORLEANS

This light rail track is mostly in "fair" condition but there is a rapid rate of electrolytic corrosion in some segments of the track where the rail is embedded in a normally damp "neutral ground." The rail joints were mostly found to be in "fair" to "poor" condition and many of the welds are broken. Expansion joints are also installed for thermal change, however, the lack of rigidity leads to broken rail ends and pumping track. Cut spikes are used to fasten the track to the wooden ties, however, with the ties embedded in the damp soil and pumping rail ends, the spikes tend to work themselves loose quickly. Most ballast, where it exists, is in "poor" condition and there is a great deal of fouling. The existing switches are of an obsolete design and replacement parts are not available. The track surface, especially in the neutral ground, is irregular where weld joints and expansion joints have failed to maintain the rigidity.

- SAN FRANCISCO

The rapid rail track is in mostly "good" to "excellent" condition except that the rail is in "fair" condition on some selected curves. These curves display more rail wear on the low rail. Rail testing by detector cars has identified some defective rails, which will require application of reinforcing straps or replacement. No signs of ballast contamination or pumping were observed and the special trackwork within the system is in "good" condition. Few signs of wear at the switch points or frogs were observed. Drainage along the entire system was judged to be in overall "good" condition and there were no signs of any problem drainage areas.

The light rail track is mostly in "excellent" condition and rail replacement is not expected to be required within the period of this study. All the girder rail is in "good" to "excellent" condition, except for a few locations. The rail fasteners and anchors within the special trackwork are also in "good" condition. All timber ties were relatively new and in "good" condition. Ballast in the tunnels and some of their approaches is in "fair" condition and some ballast is fouled with dirt. The special trackwork is in "fair" condition and some of the special trackwork units will require full or partial replacement within the next 10 years. Vegetation is growing within the ballast on some open right-of-way locations and is contributing to the fouling of ballast. However, the drainage of the embedded track within the system is "excellent".

Vegetation Growing on Fouled Ballast

The commuter rail track was not inspected since this track is currently being maintained by the Southern Pacific Railroad.

- SAN DIEGO

The light rail track is in mostly "fair" condition, but the rail on tight radius curves on the mainline shows excessive wear for its age. Rail joints are in "good" condition and the rail fastening system is in "excellent" condition. Some of the softwood ties may have to be replaced within the next few years. The ballast is in generally "good" condition, except that the track has settled in some location. The vertical restraining on the small radius curves is wearing out at a fairly rapid rate.

o Vehicles - Self-Propelled Rail Car Condition

The condition of the self-propelled rail cars on the rail transit systems is provided in Table 3.5. The rapid rail systems have 2,749 rail cars in "bad" condition, 2,196 rail cars in "poor" condition, and 1,337 rail cars in "fair" condition; most of these rail cars are located in New York City. The light rail systems have 75 rail cars in "bad" condition, 301 in "poor" condition, and 79 in "fair" condition; most of these rail cars are located in Boston, Northern New Jersey, Philadelphia, Pittsburgh, Cleveland, and New Orleans. The commuter rail systems have 131 self-propelled rail cars in "bad" condition, 640 in "poor" condition, 963 in "fair" condition; most of these rail cars are located in Boston, New York, Philadelphia, and Chicago.

A discussion of the self-propelled rail cars condition in each of the major rail areas follows, with some emphasis on items of particular concern:

- BOSTON

The rapid rail self-propelled rail cars are mostly in "fair" to "excellent" condition, with in-house rehabilitation scheduled for the rail cars in fair condition.

TABLE 3.5

SELF-PROPELLED RAIL CAR CONDITION (Each)

	Rapid Rail						Light Rail						Commuter Rail					
Major Rail Areas	E	G	F	P	B	T	E	G	F	P	B	T	E	G	F	P	B	T
Boston	120	70	144	-	-	334	-	-	-	216	-	216	-	-	-	-	46	46
New York	-	1525	988	1684	2117	6314						NA	142	24	780	408	52	1406
Northern NJ	-	90	159	34	-	283	-	-	24	-	-	24	-	300	-	227	-	527
Southern NJ	-	46	-	64	-	110						NA						NA
Philadelphia	125	-	-	244	-	369	141	67	-	85	-	293	-	251	54	5	33	343
Pittsburgh						NA	8	-	-	-	75	83	-	-	-	-	-	-
Washington, DC	18	298	-	-	-	316						NA	-	28	-	-	-	28
Chicago	206	192	46	144	560	1148						NA	44	36	129	-	-	209
Cleveland	-	-	-	26	72	98	48	-	20	-	-	68						NA
Atlanta	-	120	-	-	-	120						NA						NA
New Orleans						NA	-	-	35	-	-	35						NA
San Francisco	-	439	-	-	-	439	30	100	-	-	-	130						NA
San Diego						NA	-	24	-	-	-	24						NA
TOTAL	469	2780	1337	2196	2749	9531	227	191	79	301	75	873	186	639	963	640	131	2559

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

NA - Not Applicable

These rehabilitation programs include rebuilding trucks and suspension systems; the scope of work also includes the motors, brake packages, gears and wheels, shock absorbers, bumpers, and side bearing plates, etc.

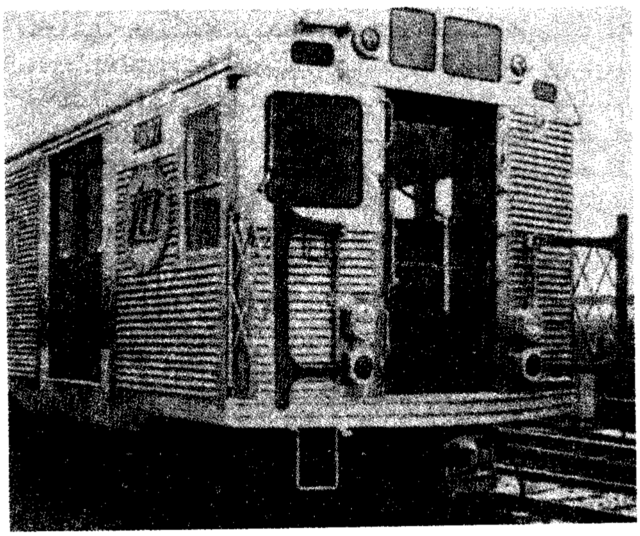
The light rail self-propelled rail cars are mostly in "poor" condition. The 92 PCC cars have recently been rehabilitated but they are 33 to 40 years old and this rehabilitation will probably not last 10 more years. The 124 Boeing light rail cars were also estimated as being in "poor" condition and expensive modifications and replacements probably would be required during the next few years.

The self-propelled rail cars, on the commuter rail line, are mostly in "bad" condition. (Note: The MBTA is planning to phase out all self-propelled commuter rail cars within the next 10 years.) These rail diesel cars are 26 to 33 years old and the propulsion systems are unserviceable. The brakes, heat and air conditioning, wiring, lights, and interiors are obsolete and badly deteriorated. The trucks and suspension systems are also deteriorated but are worth rebuilding on cars with cast truck frames. Structurally, these cars are sound (stainless steel framing and sheeting show no corrosion).

- NEW YORK

There are more than 6,300 rail cars on the rapid rail system and most of these are in "bad" to "fair" condition. The cars in "bad" condition range from 24 to 34 years of age; the cars in "poor" condition range from 18 to 23 years of age; and the cars in "fair" condition range from 15 to 18 years of age. Carbody related problems include deteriorating floors, deterioration in the bottom corners of the door openings, and corrosion of the frames for the side boxes. The appearance of the cars is impaired by wide spread vandalism and insufficient cleaning. Most cars are covered with graffiti and in many cars, physical damage (also caused by vandalism) can be observed. The prominent cause for service failures is the controllers.

Modifications of air shut-off valves, relocation of switches, and rewiring are underway to improve controller performance. The door operation and controls on some cars are in "poor" condition and have proven unreliable and would require complete replacement. Compressors on some cars also would require replacement. Traction equipment needs to be overhauled.



R-36 Car

The commuter rail system consists of over 1,400 self-propelled rail cars and most of these are either in "poor" or "fair" condition. The cars in "bad" condition are all 19 to 22 years old; the cars in "poor" condition range in age from 7 to 12 years; and the cars in "fair" condition range in age from 1 to 31 years of age. Corrosion cracks have been observed on the center sill and underframe of some of the older cars and the fiberglass front end showed cracks. Spare parts have been difficult to obtain on some of the older cars.

- NORTHERN NEW JERSEY

- The rapid rail system has 283 rail cars which range in condition from "poor" to "good". The cars in "poor" condition are 26 years old and are "worn out"; present plans are to phase out these cars. The PA-1/2 cars are 19 years old and appear to have no major structural problems. The rotating components should be replaced. The door operation and controls are in "poor" condition, have proven unreliable and need complete replacement. The compressors also should be replaced. The PA-3 cars are approximately 12 years old and no structural problems exist. The door operators are in relatively "good" condition.

Old K-Cars and Newer PA Cars

The light rail self-propelled rail cars are 30 to 37 years of age and in "fair" condition. These cars have been extremely well maintained and replacement parts are available. However, the step wells and step well structures have deteriorated.

The self-propelled rail cars on the commuter rail system are mostly in either "poor" or "good" condition. The vehicles in "poor" condition range in age from 16 to 72 years. Most of these older cars will either require extensive rehabilitation for conversion to push-pull coaches or retirement when the re-electrification is complete. However, some of the self-propelled rail cars, that are only 12 years old, have been experiencing insulation breakdown and the truck components are worn. Although the seating is in "good" repair, the current 2-2 seating is planned to be replaced with a 3-2 arrangement found on the remainder of the fleet. Several subsystems have also become obsolete, including the engineman's gauges, spin-slide control, storage batteries, PA system, and warning lights.

- SOUTHERN NEW JERSEY

The rapid rail system has 110 rail cars. The 64 cars in "poor" condition are approximately 15 years old and the 46 cars in "good" condition are 2 years old. Insulation on the older cars is "poor" and has reached its life expectancy. Stress corrosion has occurred at the welded sills. The floors have rotted at the side door entrances on these older cars. The load weigh control is in "poor" condition on the older cars and failures are a common cause of inoperation.

- PHILADELPHIA

Most of the self-propelled rail cars on the rapid rail system are in "poor" condition, although some are in "excellent" condition. Rail cars in "poor" condition range in age from 15 to 24 years. Wire insulation is "poor" on these cars and has reached its life expectancy. On some cars, Stress corrosion has occurred at the welded sills; the flooring has rotted at the side door entrances; and in some cases, maintenance and necessary overhauls have been deferred.

Although most of the light rail self-propelled rail cars are in "good" and "excellent" condition, nearly 85 are in "poor" condition. The rail cars in "poor" condition range in age from 37 to 60 years; the traction equipment is obsolete, and these cars are unsuitable for rehabilitation and should be replaced.

The self-propelled rail cars on the commuter rail system are mostly "fair" or "good" although 38 are either "bad" or "poor". The cars in "poor" and "bad" condition range in age from 26 to 53 years.

- PITTSBURGH

The light rail system includes 83 self-propelled rail cars and 75 of these are in "bad" condition. These rail cars are approximately 36 years old and most of the subsystems and components are in "poor" condition and require replacement. The truck framing, some side sheeting containing the window opening, center sills of the frame, rebuilt motors and gear boxes are being reused in the reconstruction program.

- WASHINGTON, DC

The rapid rail system includes 316 rail cars, all of which are either in "good" or "excellent" condition.

Self-Propelled Rail Car

The commuter rail system includes 28 RDC's, which have all been rebuilt in the last 6 years and are in "good" condition. Structurally, they are in "excellent" repair. However, the RDC's are 30 years old and obsolete. These cars have different kinds of trucks, bearings, and other equipment. Two different diesel engines are used with two different transmissions. This equipment is expensive to operate because of problems in maintenance due to the diversity of the equipment onboard.

- CHICAGO

The rapid rail system contains 1,148 self-propelled rail cars; 560 of these are in "bad" condition and 144 are in "poor" condition. The rail cars in "bad" condition range in age from 19 to 33 years and the rail cars in "poor" condition are approximately 14 years old. Couplers and draft gear are worn from years of use; the plywood floors have soft spots around all doorways, the window regulators are worn out and many are not operable. The car interiors show age; they have been painted and reupholstered but never rehabilitated. The trucks have been overhauled many times but the propulsion system has deteriorated and is one of the biggest maintenance items. All of the electrical equipment is old and requires higher maintenance; in addition, it is difficult to obtain replacement parts for this older type of equipment.

The commuter rail system includes 209 self-propelled rail cars and most of these are in "fair" condition. The rail cars are 12 years old and have rust related problems on the fiberglass car ends, door frames and at the laps and side sheets. In addition, the trucks, couplers, air compressors, and traction motors require improvement.

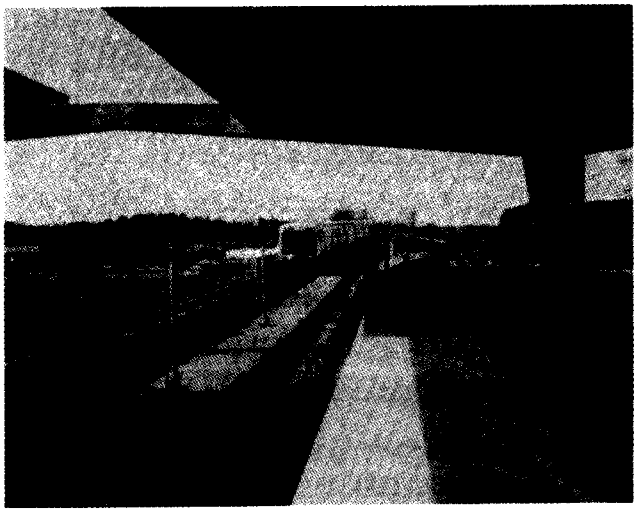
- CLEVELAND

The rapid rail system includes 98 self-propelled rail cars and all of these are either "bad" or "poor". The older cars are being replaced.

The light rail system includes 68 self-propelled rail cars. Forty-eight of these are new and the others will be retired.

- ATLANTA

This rapid rail system includes 120 self-propelled rail cars, all of which are less then 5 years old. Some minor problems exist and these include seats which have metal frames that eventually punch through the seat upholstery with use, excessive wheel flange wear due to the tighter turns, parking brakes on the cars which have resulted in the possibility of applying or releasing the brakes unknowingly and minor problems with the movable cab windows.



Self-Propelled Rail Car

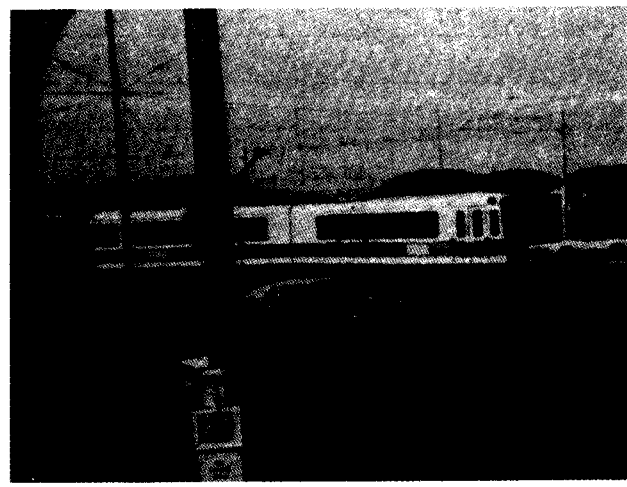
- NEW ORLEANS

This light rail system includes 35 rail cars, all of which are approximately 60 years old. These rail cars are in "fair" condition and the brakes and power controllers, door operators, light, body and other components have been well maintained. The air compressors, truck parts and other undercarriage components have been regularly inspected and maintained and are in "fair" condition. Alternative equipment has been utilized to replace various outmoded components. Other alternative components have been identified to replace the old vehicle equipment parts that are becoming hard to maintain.

- SAN FRANCISCO

The rapid rail system includes 439 self-propelled rail cars; these are all in "good" condition and approximately 13 years old. A fire-hardening rehabilitation program was instituted after the tunnel fire and a complete interior changeout was initiated, including new floors, carpets, liners, seats, and interior walls. Propulsion overloads have caused some flashovers at the low voltage thyristor. These problems are being overcome with a motor rewind program.

The light rail system includes 130 rail cars, all of which are either in "good" or "excellent" condition.



Light Rail Car

- SAN DIEGO

This light rail system includes 24 rail cars, all of which are in "good" condition and only 3 years old.

o Vehicles - Locomotive and Unpowered Car Condition

The condition of the commuter rail locomotives and unpowered cars is provided in Table 3.6. The commuter rail systems have 416 locomotives and 11 of these (all in San Francisco) are in "bad" condition, 56 are in "poor" condition (mostly in New York and Boston), and 145 are in "fair" condition (mostly in New York, Northern New Jersey, and Chicago). There were 1,671 unpowered cars and 50 are in "bad" condition (all in San Francisco and Boston), 169 in "poor" condition (all in New York, Northern New Jersey, and San Francisco), and 538 in "fair" condition (mostly in New York and Northern New Jersey).

TABLE 3.6

COMMUTER RAIL LOCOMOTIVE AND UNPOWERED CAR CONDITION (Each)

Major Rail Areas	Locomotives						Unpowered Cars					
	E	G	F	P	B	T	E	G	F	P	B	T
Boston	-	18	-	19	-	37	74	60	-	-	23	157
New York	-	59	52	24	-	135	9	8	290	82	-	389
Northern NJ	-	27	46	13	-	86	117	-	152	56	-	325
Southern NJ						NA						NA
Philadelphia						NA						NA
Pittsburgh	-	2	-	-	-	2	-	10	-	-	-	10
Washington, DC	-	6	-	-	-	6	-	22	-	-	-	22
Chicago	-	89	37	-	-	126	-	614	81	-	-	695
Cleveland						NA						NA
Atlanta						NA						NA
New Orleans						NA						NA
San Francisco	-	3	10	-	11	24	-	-	15	31	27	73
San Diego						NA						NA
TOTAL	-	204	145	56	11	416	200	714	538	169	50	1671

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

NA - Not Applicable

A discussion follows of the condition of these commuter rail locomotives and unpowered cars, with some emphasis on items of particular concern:

- BOSTON

The 19 locomotives were originally built in the 1950's and although they have been rebuilt, they are unreliable and obsolete. The unpowered cars are 37 years old and although they were rebuilt in 1977 and 1978, they are worn out and obsolete. The steel framing under the stainless sheeting is rusting, air conditioning, trucks, and wiring are in "poor" condition and although the vehicle braking meets the FRA inspection requirements, it is obsolete.

- NEW YORK

The 24 locomotives are in "poor" condition and are 24 to 28 years old. Although some of these units are being rehabilitated, some are being retired because of difficulty in obtaining spare parts. The locomotives in "fair" condition range in age from 6 to 33 years. The unpowered cars in "poor" condition range in age from 35 to 46 years and are obsolete. The use of steam for heat and air conditioning is much less reliable then the electric head end power and parts are difficult to obtain. The unpowered cars in "fair" condition are 21 to 28 years old and, due to regularly scheduled overhauls, the interior of the coaches are pleasant and the seats are comfortable.

Unpowered Rail Car

- NORTHERN NEW JERSEY

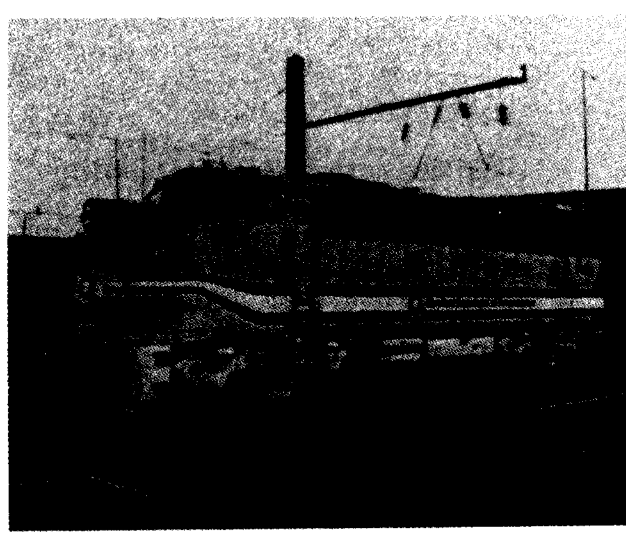
The locomotives in "poor" condition are 31 to 34 years old and all of the rotating equipment is worn and overdue for repair. Main alternators are worn and unreliable, all the truck components are worn out, traction motor windings have experienced grounds because the insulation has broken down; air compressors pump oil throughout the system and the mechanical drives for the cooling fans, equipment blowers, and hotel power are all in "bad" condition. The locomotives in "fair" condition are 11 to 16 years old and rotating equipment, selective wiring, and electric head end power are being rehabilitated to make them compatible with the rest of the fleet. The unpowered cars in "poor" condition are 19 to 37 years old and are obsolete due to their steam heat systems. The unpowered cars in "fair" condition are 11 to 13 years old and require new glazing, interior refurbishment, and other work. The 480-volt cables experience insulation breakdown and the truck components are worn. Other subsystems have become obsolete over time, including the engineman's gauges, spin-slide control, storage batteries, PA system, and warning lights.

- PITTSBURGH

The locomotives and unpowered cars are only 2 years old and all are in "good" condition.

- WASHINGTON, DC

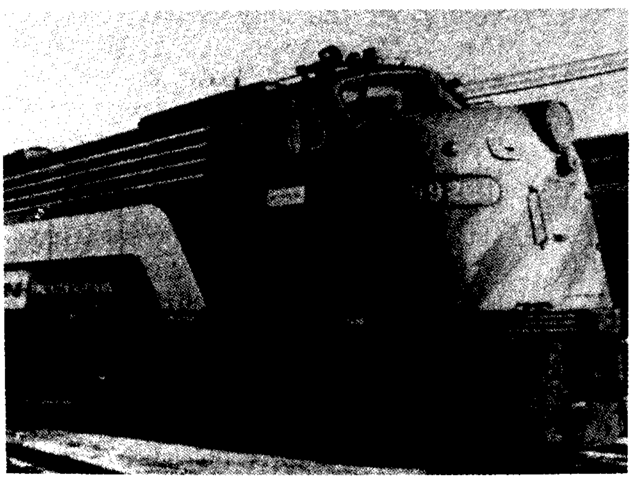
The locomotives were rebuilt 3 years ago and are in "good" condition; the only problem is the low horsepower. Although adequate for the 5-car trains now operated, these locomotives will not be able to pull longer trains without slowing the rate of acceleration, and thus affecting the schedule. The unpowered cars were rebuilt 2 years ago and also are in "good" condition. However, the unpowered cars are not currently fitted with control cabs for push-pull operation, although the trainline cables were installed during rehabilitation.



Locomotive

- CHICAGO

The locomotives in "fair" condition have rusted areas on the nose, under the cab doors, and on the doors themselves. The head end power units are obsolete and failure prone. Some locomotives also have windshield leaks; exhaust stack silencer and motor braker problems also exist. The unpowered cars in "fair" condition are 19 to 23 years old. These stainless steel cars are well maintained and the minor problems can be repaired.



Locomotive

- SAN FRANCISCO

The locomotives in "bad" condition are approximately 30 years old and it has been very difficult to maintain and acquire spare parts. These locomotives are underpowered for commuter service, rendering them unable to recover lost schedule times or to maintain current schedules in the face of heavy passenger loads. The locomotives in "fair" condition are approximately 17 years old and are being rebuilt. The unpowered cars in "bad" condition are between 57 and 60 years old and spare parts are no longer produced or available. Currently, some of these vehicles are being cannibalized for spare parts to use in the serviceable unpowered cars. The unpowered cars in "poor" condition are 27 to 29 years old and spare parts are no longer produced.

o Power Distribution Substation Condition

The condition of the substations for the rail transit systems is provided in Table 3.7. The rapid rail systems have 456 substations and 6 of these are in "bad" condition (Boston), 131 in "poor" condition (New York), and 5 in "fair" condition (Philadelphia). The light rail transit systems have 60 substations, 6 of these are in "poor" condition (Boston and Pittsburgh), 7 of these are in "bad" condition (Philadelphia and Boston) and only 1 in "fair" condition (New Orleans). The commuter rail systems have 157 substations and 30 of these are in "bad" condition (mostly in New York), 17 in "poor" condition (82 percent in Philadelphia), and 27 in "fair" condition (mostly in New York).

A discussion of the substation condition in each of the major rail areas follows, with some emphasis on items of particular concern:

TABLE 3.7

SUBSTATION CONDITION (Each)

Major Rail Areas	Rapid Rail						Light Rail						Commuter Rail					
	E	G	F	P	B	T	E	G	F	P	B	T	E	G	F	P	B	T
Boston	7	13	-	2	5	27	3	2	-	2	3	10						NA
New York	1	86	-	117	-	204						NA	11	64	19	-	25	119
Northern NJ	-	6	-	1	-	7						NA	-	-	1	-	5	6
Southern NJ	-	10	-	-	-	10						NA						NA
Philadelphia	-	12	5	11	-	28	4	-	-	-	4	8	-	-	-	14	-	14
Pittsburgh						NA	-	-	-	4	-	4						NA
Washington, DC	68	-	-	-	-	68						NA						NA
Chicago	5	36	-	-	1	42						NA	7	1	7	3	-	18
Cleveland	-	10	-	-	-	10	2	2	-	-	-	4						NA
Atlanta	23	-	-	-	-	23						NA						NA
New Orleans						NA	-	-	1	-	-	1						NA
San Francisco	-	37	-	-	-	37	2	10	-	-	-	12						NA
San Diego						NA	21	-	-	-	-	21						NA
TOTAL	104	210	5	131	6	456	32	14	1	6	7	60	18	65	27	17	30	157

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

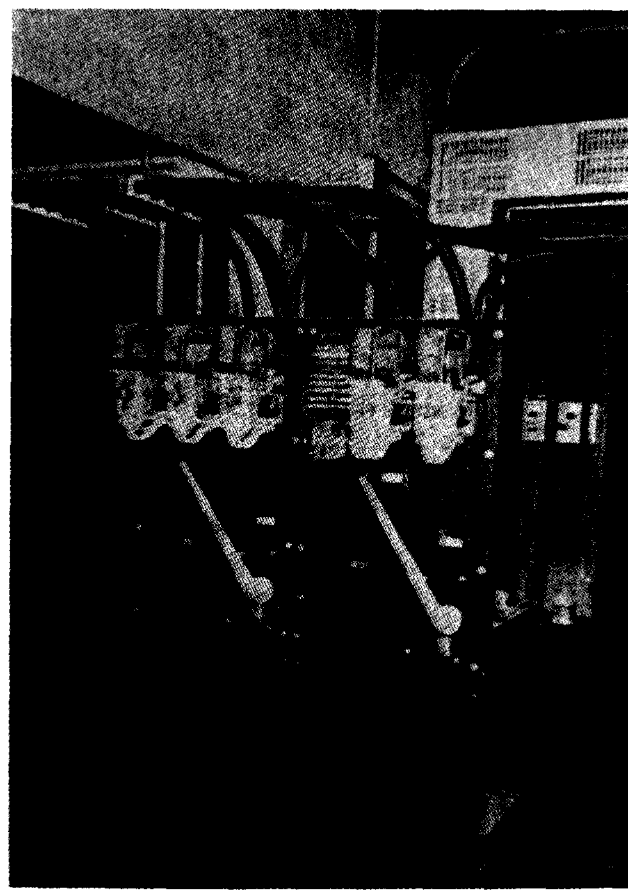
NA - Not Applicable

- BOSTON

Of the 37 substations, 7 are over 50 years old and 1 is 24 years old. Eight of these substations are in "bad" condition and are scheduled to be replaced at the end of 1984 by units under construction. The other units are in "poor" condition but are used only intermittently. The remaining substations are either new since 1970, or have undergone improvements such that their condition is "good" to "excellent". The substations provide power to both the rapid rail and light rail systems.

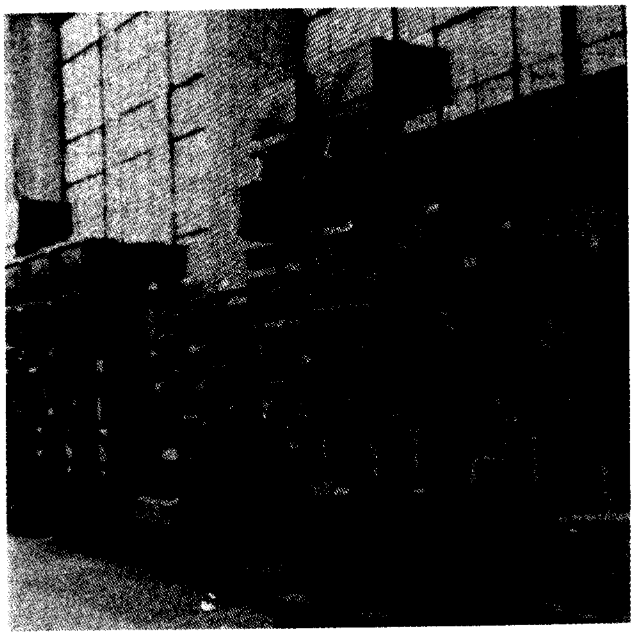
- NEW YORK

On the rapid rail systems, the substations in "poor" condition are 24 to 73 years old. Some of the transformers are oil-immersed, air-cooled units and although they are in "good" condition, some are contaminated with PCB. Some of the transformers also have circuit breakers that show signs of rust



Negative Return Board

and corrosion which should be repaired; one also leaks oil. The rectifier units are well maintained but some are 60 years old and spare parts are no longer available.

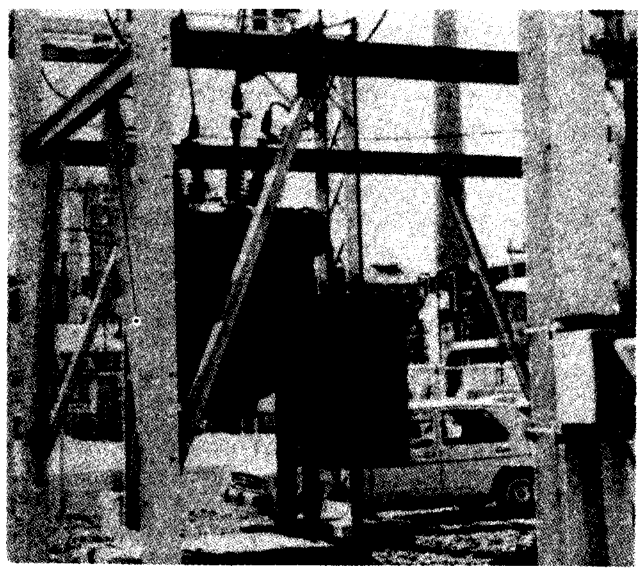


AC Transformer Primary

On the commuter rail line, the substations in "bad" condition are 40 to 70 years old. AC primary switchgear used on the currently electrified segments of these lines include oil break circuit breakers and air magnetic circuit breakers; the switchgear has exceeded its design life and is in "poor" condition. Many of the transformers are contaminated with PCB; they are in "poor" condition. Overall, the rectifiers are in "poor" condition and spare parts are no longer available for the rotary convertor and mercury arc units. Much of the equipment used with the DC switchgear has exceeded its design life and is in "poor" condition. The substations in "fair" condition are approximately 45 years old and although the equipment has been well maintained, some of the older equipment shows signs of rust and corrosion.

- NORTHERN NEW JERSEY

There are 7 substations on the rapid rail system and 6 of these are in "good" condition and 1 is in "poor" condition. The AC line protection and transformer/rectifier protection are in "excellent" condition. Transformers are oil-immersed, air-cooled units and although they are in "good" condition, they are contaminated with PCB. The rectifiers are of silicone diode, forced-air types and are in "good" condition.



Oil Break Circuit Breakers

The substations on the light rail system are owned by Public Service Electricity & Gas Company and were not inspected.

The substations on the commuter rail system are approximately 54 years old and are in "bad" condition. The AC primary switchgear, which was installed in the original substations consists of General Electric oil circuit breakers; they have exceeded their design life and are in "bad" condition. The General Electric oil-immersed, air-cooled transformers were installed in these older substations and they are near the end of their useful life and are consequently in "bad" condition. The rectifying units, installed in the original substations, are General Electric 12 anode and 6 anode mercury arc rectifiers; this type of rectifier is now obsolete and spare parts are not available. The General Electric DC air circuit breakers have also exceeded their design life and are in "poor" condition.

- SOUTHERN NEW JERSEY

The rapid rail system has 10 substations that were installed between 1969 and 1975; these substations are in "good" condition.

- PHILADELPHIA

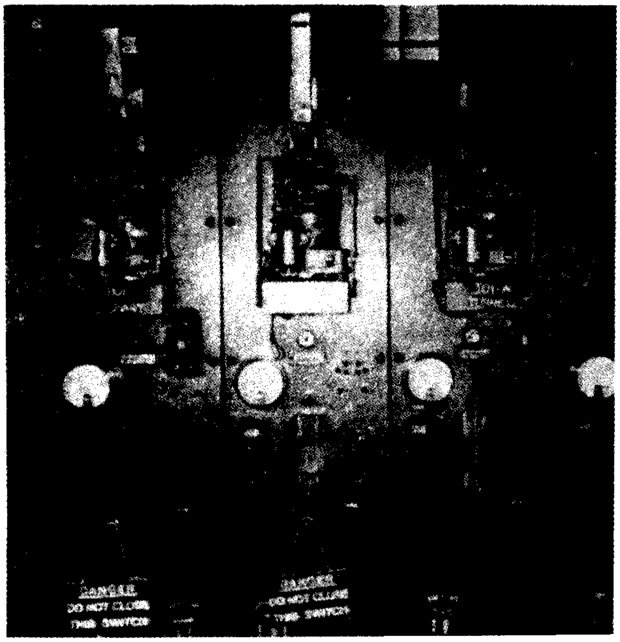
The 11 rapid rail substations in "poor" condition range in age from 55 to 70 years. The DC transformer primaries are in "poor" condition, with spare parts not available. The rectifiers are now obsolete and spare parts are only available from similar units taken out of service. The DC switchgear is in "fair" condition, although spare parts are generally not available. The substations in "fair" condition are approximately 30 years old and spare parts are also not readily available. The transformers are in "fair" to "poor" condition but some have been found to contain PCB. Mercury arc rectifiers are no longer produced and spare parts must be taken from out of service units.

The 4 substations on the light rail system, in "bad" condition, are approximately 64 years old. The air break switches and the protective switchgear which uses oil circuit breakers have exceeded the original design life. Transformers are in "poor" condition and one that has to be replaced contains PCB. The rectifiers are rotary converters that are well maintained but are no longer manufactured and no spare parts are available. The panel mounted air circuit breakers are in "poor" condition and the feeder cables should be replaced; the insulation is worn and frayed.

On the commuter rail system, the substations are 50 to 60 years old and in "poor" condition because their 1920 and 1930 vintage equipment are near the end of their useful life and spare parts are no longer available.

- PITTSBURGH

The power substations on the light rail system are approximately 84 years old and are in "poor" condition. The fusible disconnects, for transformer protection on the primaries, threaten reliability. The transformers are oil-immersed and air-cooled and have a physical design that is no longer manufactured. These transformers are also incompatible with modern silicone diode rectifiers. The existing rotary convertor rectifiers have exceeded their design life and spare parts are no longer available.



Mounted Air Circuit Breakers

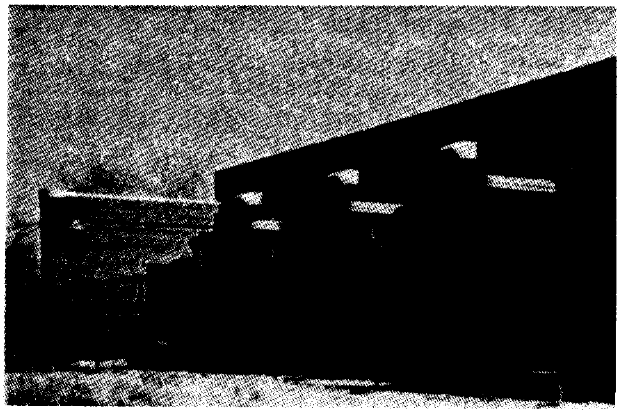
- WASHINGTON, DC

The rapid rail system has 68 substations and all are in "excellent" condition. The substations are all less than 10 years old.

- CHICAGO

The rapid rail system has 42 substations and only one is in "bad" condition. The equipment in the substations is either new or has been included in improvement programs since 1961. The substation in "bad" condition is over 24 years old and the equipment is scheduled for replacement or retirement.

The commuter rail systems have 18 substations and 3 of these substations are in "poor" condition; these substations are 55 years old and although they have undergone some partial modernization, much of the equipment is at the end of its useful life. The seven substations in "fair" condition are also approximately 55 years old and are being modernized. The cables are being renewed as the substations are modernized.



Outdoor Transformer

- CLEVELAND

The rapid rail system has 10 substations which are 15 to 28 years old. However, due to the regular performance of operational and routine maintenance testing procedures incorporated into the transit system maintenance program, the life of the various subsystems and components have been extended for at least five years.

The 4 substations on the light rail system are either in "good" or "excellent" condition.

- ATLANTA

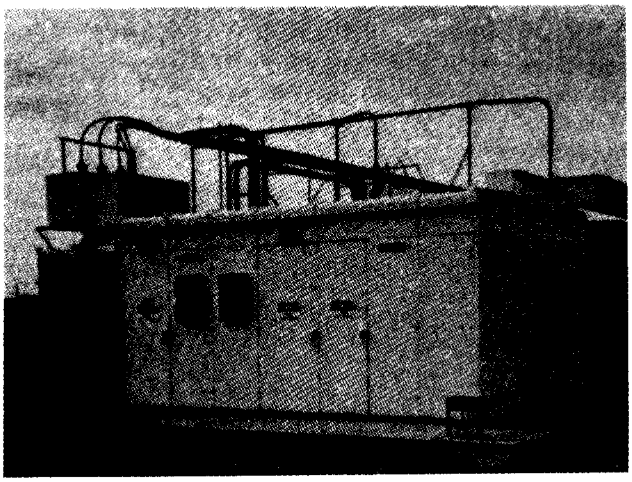
The rapid rail system has 23 substations and all are in "excellent" condition. These substations are approximately 5 years old.

- NEW ORLEANS

This system has 1 substation in "fair" condition, which is approximately 91 years old. In general the equipment is well designed, properly maintained and suitable. However, the equipment is no longer manufactured and as a result, future repair and replacement may be difficult. Switchgear modifications to allow switching between transformers, rectifiers, and circuit breakers would be desirable to provide greater flexibility and failure recovery and maintainability.

- SAN FRANCISCO

  The 37 substations on the rapid rail system are all in "good" condition. The substations on the rapid rail system are approximately 13 years old. The 12 substations on the light rail system are in either "good" or "excellent" condition. The substations on the light rail system are between 2 and 8 years old.



Substation

- SAN DIEGO

  The light rail system has 21 substations and these are 1 to 3 years old and in "excellent" condition.

o Power Distribution - Overhead Wire Condition

  The condition of the overhead wire for the nation's rail transit systems is provided in Table 3.8. The rapid rail systems have 70 miles of overhead wire and all of this is in "good" condition. The light rail systems have approximately 470 miles of overhead wire and approximately 38 miles is in "poor" condition (45 percent in Boston) and 55 miles is in "fair" condition (mostly in Philadelphia, Boston and New Orleans).

  A discussion of the condition of the overhead wire in each of the major rail areas follows, with some emphasis on items of particular concern:

- BOSTON

  The 8 miles of catenary for the rapid rail system is approximately 14 years old and is in "good" condition.

  The light rail system has 55 miles of overhead wire and 17 miles is in "poor" condition and 19 miles is in "fair" condition. The wire in "poor" condition is approximately 54 years old. The cable, ducts, trolley wire and poles are in "poor" condition. The positive cables are "poor" and the negative cables are "bad". The trolley wire in "fair" condition is approximately 39 years old. The equipment condition ranges from "poor" to "good".

- NEW YORK

  The commuter rail system has approximately 275 miles of overhead wire and it is all in "bad" condition. This wire is approximately 69 years old. The main messenger wire is steel and is in "poor" condition. The

TABLE 3.8

OVERHEAD WIRE CONDITION (Miles)

Major Rail Areas	Rapid Rail						Light Rail						Commuter Rail					
	E	G	F	P	B	T	E	G	F	P	B	T	E	G	F	P	B	T
Boston	-	8	-	-	-	8	-	19	19	17	-	55						NA
New York						NA						NA	-	-	-	-	275	275
Northern NJ						NA	-	-	-	9	-	9	-	-	87	-	-	87
Southern NJ						NA						NA						NA
Philadelphia						NA	-	253	22	-	-	275	-	69	58	111	-	238
Pittsburgh						NA	12	-	-	12	-	24						NA
Washington, DC						NA						NA						NA
Chicago	-	5	-	-	-	5						NA	3	29	159	-	-	191
Cleveland	-	39	-	-	-	39	20	-	-	-	-	20						NA
Atlanta						NA						NA						NA
New Orleans						NA	-	-	14	-	-	14						NA
San Francisco						NA	-	41	-	-	-	41						NA
San Diego						NA	28	4	-	-	-	32						NA
TOTAL	-	70	-	-	-	70	60	317	55	38	-	470	3	99	309	125	275	811

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

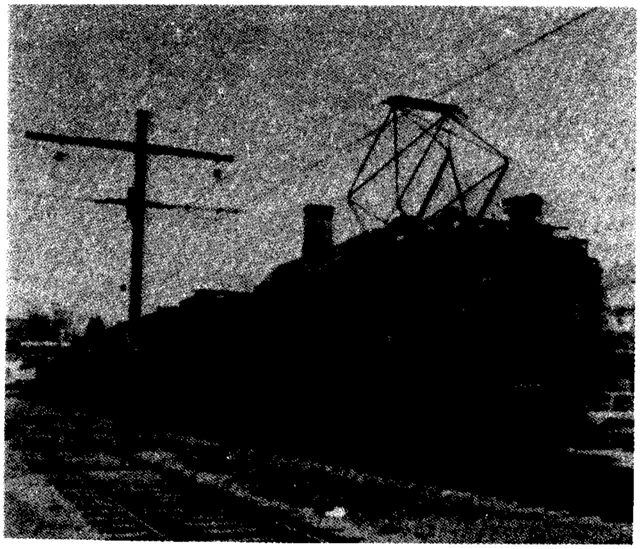
NA - Not Applicable

auxiliary messenger wire is pure copper and is in "fair" or "good" condition. Approximately 10 miles of the contact wire is renewed annually, as needed. The steel structures, used to support the overhead wire throughout the system, are in "fair" condition. Overall, the hardware is in "bad" condition and many of the spare parts are no longer available.

- NORTHERN NEW JERSEY

The light rail system has approximately 9 miles of overhead wire and the age of the wire varies throughout the line; the overall condition is "poor". Steel poles with concrete foundations providing support for the catenary line were originally installed on the trolley line and their condition is "poor".

The commuter rail system has approximately 87 miles of overhead wire, which is nearly 50 years old. This wire was estimated as being in "fair" condition and is replaced as needed as part of the electrification program. An additional feeder wire is also being installed so that the existing catenary system can be operated on the new AC system.



DCMU Motor Car

- PHILADELPHIA

The light rail system has approximately 279 miles of overhead wire and it is in mostly "good" condition. This wire is between 6 and 9 years old.

The commuter rail system has 238 miles of overhead wire; 111 miles is in "poor" condition and 58 miles is in "fair" condition. However, the 58 miles of catenary in "fair" condition should be replaced.

- PITTSBURGH

The light rail system has 29 miles of overhead wire; 12 miles is in "poor" condition and the other 17 is in "excellent" condition. The catenary in "poor" condition is the direct suspension overhead type which is outdated and inadequate. The other wire is brand new.

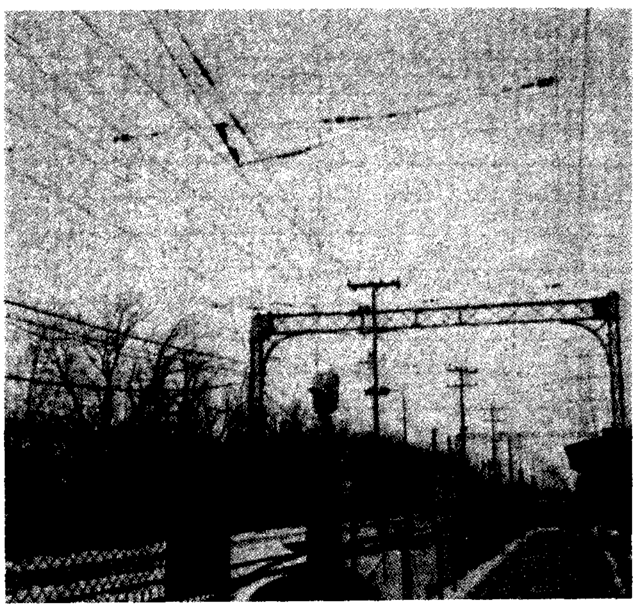
- CHICAGO

The rapid rail system has 5.1 miles of overhead wire and it is all in "good" condition.

The commuter rail system has approximately 191 miles of overhead wire and 159 miles is in "fair" condition. The overhead wire in "fair" condition is between 55 and 58 years old. The older messenger cables are approximately 60 years of age and are subject to failures; cables of this age become brittle and the steel core shows signs of deterioration and rust. The secondary cable is also the same age and is structurally weakened. The supporting clips connecting to the secondary cable have also weakened and the secondary cable is in sections. This secondary cable has snapped in periods of extremely cold weather.

- CLEVELAND

The rapid rail system has approximately 39 miles of overhead wire; all in "good" condition. The light rail overhead wire is new and is in "excellent" condition.



Overhead Wire

Overhead Catenary

- NEW ORLEANS

  The New Orleans light rail system has approximately 14 miles of overhead wire and it is in "fair" condition. 65 percent of the catenary wire is the circular-type wire, as originally installed. This wire is now being replaced with the grooved-type wire, which is more compatible with the new carbon sliding connectors presently being used on the streetcars.

- SAN FRANCISCO

  The San Francisco light rail system has 41 miles of overhead wire and it is all in "good" condition.

- SAN DIEGO

  This light rail system has about 32 miles of overhead wire and it is all in either "excellent" or "good" condition.

o Power Distribution - Third Rail Condition

  The condition of the third rail for the rail transit systems is provided in Table 3.9. The rapid rail systems have approximately 1,378 miles of third rail and 38 is in "bad" condition, 406 in "poor" condition and 365 miles is in "fair" condition. Most of the third rail in "poor" or "fair" condition is located on the New York transit systems. The light rail systems contain approximately 28 miles of third rail and 24 is in "bad" condition and 4 in "good" condition, all located on the Philadelphia light rail system. The commuter rail systems have 489 miles of third rail and 187 miles is in "bad" condition and about 76 miles is in "poor" condition; all located on the New York transit systems.

  A discussion of the condition of the third rail in each of the major rail areas follows, with some emphasis on items of particular concern:

TABLE 3.9

THIRD RAIL CONDITION (Miles)

	Rapid Rail						Light Rail						Commuter Rail					
Major Rail Areas	E	G	F	P	B	T	E	G	F	P	B	T	E	G	F	P	B	T
Boston	16	36	-	23	-	75						NA						NA
New York	-	-	326	363	-	689						NA	60	166	-	76	187	489
Northern NJ	-	-	29	-	-	29	-	-	-	-	-	None	-	-	-	-	-	None
Southern NJ	-	29	-	-	-	29						NA						NA
Philadelphia	-	47	10	-	-	57	-	4	-	-	24	28						NA
Pittsburgh						NA						NA						NA
Washington, DC	-	98	-	-	-	98						NA						NA
Chicago	-	160	-	20	38	218						NA						NA
Cleveland						NA						NA						NA
Atlanta	35	-	-	-	-	35						NA						NA
New Orleans						NA						NA						NA
San Francisco	-	148	-	-	-	148						NA						NA
San Diego						NA						NA						NA
TOTAL	51	518	365	406	38	1378	-	4	-	-	24	28	60	166	-	76	187	489

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

NA - Not Applicable

- BOSTON

The rapid rail system contains 75 miles of third rail; 23 miles is in "poor" condition. The third rail in "poor" condition is approximately 54 years old.

- NEW YORK

The New York rapid rail system has approximately 689 miles of third rail; 363 miles is in "poor" condition and 326 miles is in "fair" condition. The age of this rail was not available.

The commuter rail system contains approximately 489 miles of third rail; 187 miles is in "bad" condition and about 76 miles is in "poor" condition. The third rail in "bad" condition ranges in age from 34 to 69 years and the rail in "poor" condition is approximately 65 years old.

New 150 lb Third Rail

- NORTHERN NEW JERSEY

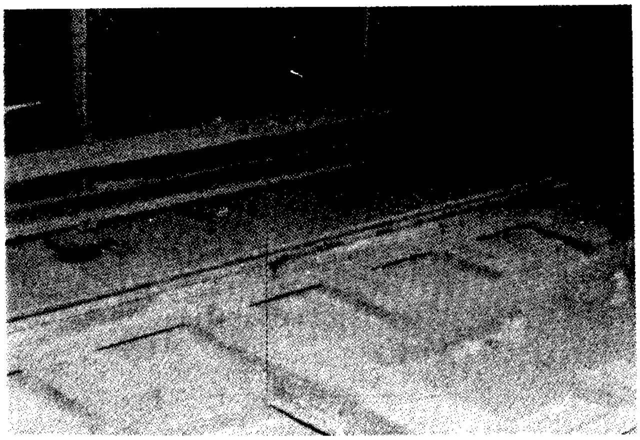
The rapid rail system has 29 miles of third rail that is in "fair" condition. Approximately 70 percent of this rail was replaced in the late 1960's and since that time, repairs and replacements have been made randomly as needed. The condition of the coverboard varies from "good" to "poor" throughout the system. Feeder cables and duct are approximately 70 years old and in "poor" or "bad" condition since they were not replaced during the modernization of the traction power substation in the 1970's.

- SOUTHERN NEW JERSEY

The rapid rail system has approximately 29 miles of third rail which is in "good" condition. However, the coverboards are in "poor" condition and would require improvement.

- PHILADELPHIA

The rapid rail system has approximately 57 miles of third rail and 10 miles of this is in "fair" condition and the remainder in "good" condition. The third rail in "fair" condition is approximately 24 years old.

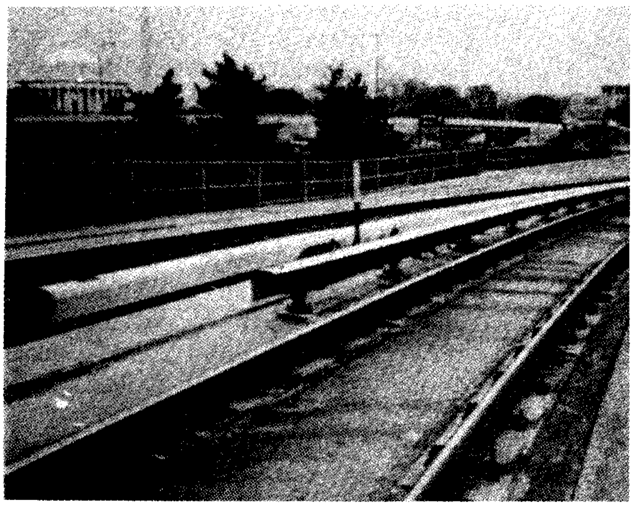


Third Rail

The light rail system has 28 miles of third rail and 24 of this is in "bad" condition and the remainder is in "good" condition. The third rail in "bad" condition is almost 74 years old.

- WASHINGTON, DC

The rapid rail system has 98 miles of third rail and all of this third rail is in "good" condition.



Third Rail

- CHICAGO

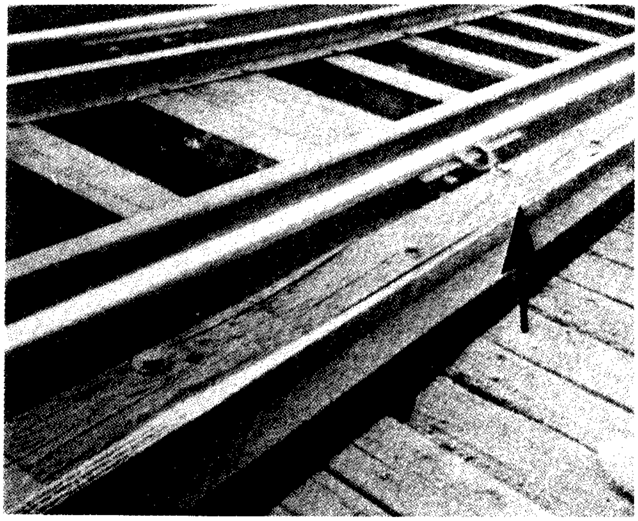
The rapid rail system has 218 miles of third rail; 38 miles of this third rail is in "bad" condition and 20 miles is in "poor" condition. The third rail in both "poor" and "bad" condition is more than 30 years old and would have to be rehabilitated or modernized.

- ATLANTA

The rapid rail system has 35 miles of third rail and it is all in "excellent" condition.

- SAN FRANCISCO

The rapid rail system has 148 miles of third rail and all of it is in "good" condition.



Chicago Transit Authority
Third Rail (Note Defective Rail)

o System-Wide Controls Condition

The condition of the system-wide controls for the rail transit systems is summarized in Table 3.10. The system-wide controls element includes a train control subsystem, a communication subsystem, and a supervisory and control subsystem. Each of these subsystems contain various components comprised of units/equipment that perform the system-wide control functions. These individual subsystems were evaluated separately and the summary evaluation for the entire element is given in Table 3.10 for each of the designated major rail areas.

A discussion of the system-wide controls condition in each of the major rail areas follows, with some emphasis on items of particular concern:

TABLE 3.10

SYSTEM-WIDE CONTROL CONDITION (Each)

Major Rail Areas	Rapid Rail				Light Rail				Commuter Rail			
	TC	CO	S&C	SUM	TC	CO	S&C	SUM	TC	CO	S&C	SUM
Boston	F/G	F/G	F/G	F/G	P	F/G	F	F	G	G	G	G
New York	F/G	F/G	F/G	F/G				NA	F/E	F/G	F/G	F/G
Northern NJ	F/E	F/G	F/G	G	G	P	F	F	F/E	F/G	G	G
Southern NJ	F/G	P/F	G	F				NA				NA
Philadelphia	F/G	F/E	G	G	G/E	F/E	G	G	P/G	P/E	F	F
Pittsburgh				NA	P	F	F	F	G	G	G	G
Washington, DC	B/G	G	G	G				NA				NA
Chicago	G	G/E	G	G				NA	P/E	P/G	F/E	F
Cleveland	F/G	P/G	F	F	F/G	G/E	G	G				NA
Atlanta	G/E	G/E	G	G				NA				NA
New Orleans				NA				NA				NA
San Francisco	F/G	F/G	F/G	F/G	G/E	F/E	G	G				NA
San Diego				NA	G	G	G	G				NA

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad

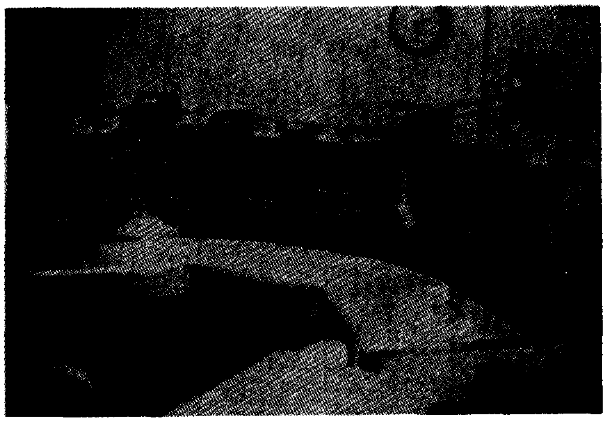
TC - Train Control CO - Communications

S&C - Supervisory and Control SUM - Summary Evaluation

NA - Not Applicable

- BOSTON

The system-wide controls for the rapid rail system vary from 8 to 30 years of age. The wayside automatic train protection equipment is approximately 30 years old and it was estimated that it was in "fair" condition. The vehicle-borne automatic train protection system is approximately 8 years old and these 162 units were estimated as being in "good" condition. The train supervision and system status indicators/alarms are approximately 9 years old and these were in "good" condition. The overall summary condition for the train control subsystem is estimated as "fair" to "good". The communications subsystem includes PA systems, hand-carried radio units, power supervision links, telephones, train control links, CCTV, and voice recording units; this equipment was all estimated as being in "fair" to "good" condition. The supervisory and control subsystem includes status boards and displays for both traction power and facilities and these were all estimated as being in "good" condition. In summary, the system-wide controls for the rapid rail system was estimated as being "fair" to "good".



CTC Machine for Medium-Size Interlocking

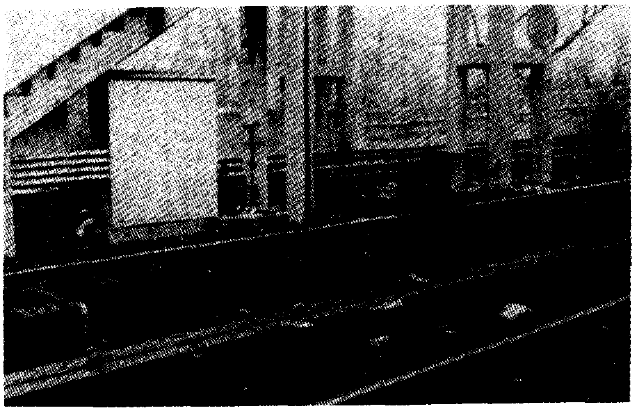
The train protection component for the light rail system is approximately 46 years old and it was estimated that these wayside units were in "poor" condition. The communications system included hand-carried radios, data links, a PA system, vehicle-borne radio units, and voice recording units, all of which were estimated as being in "fair" to "good" condition. The supervisory and control subsystem includes status boards and displays and these were estimated as being in "good" condition. In summary, the system-wide controls for the light rail system was estimated as being in "fair" condition.

The train protection component for the commuter rail system is approximately 23 years old and was estimated as being in "good" condition. The communications subsystem includes data recording units, cable carrier, telephones, PA systems, radios, and CCTV, and these were all estimated as being in "good" to "excellent" condition. The supervisory and control subsystem includes facilities supervision and this was estimated as being in "good" condition although it is approximately 13 years old. In summary, the system-wide controls for the commuter rail system was estimated as being "good".

Vintage Wayside Signal

- NEW YORK

The train control subsystems for the rapid rail systems consist of wayside automatic train protection, system status indicators/alarms, train operations controls, dispatching devices, vehicle-borne automatic train protection units, route controls, station graphics controls, and central automatic train control protection equipment; these were all estimated as being in "fair" to "excellent" condition. The communications subsystem includes a wide variety of telephones, PA units, radios, CCTV, train control links, and vehicle-borne and wayside/local radio units, which vary in age from 8 to 54 years. This equipment was all estimated as being in "fair" to "good" condition. The supervisory and controls subsystem includes status boards/displays for traction power supervision and facilities supervision. This equipment is all approximately 10 years old and were estimated as being in "fair" to "good" condition. The summary evaluation for the system-wide controls for the rapid rail system indicates a "fair" to "good" condition.



Wayside Signal and Equipment Case

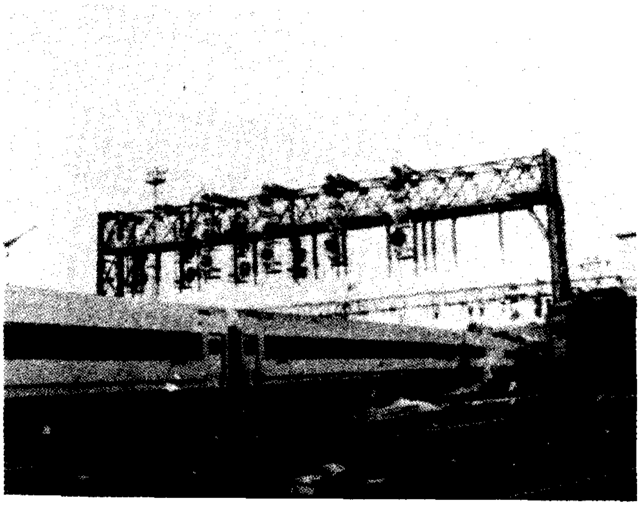
The commuter rail train control subsystem includes wayside and vehicle-borne automatic train protection equipment, route controls, dispatching devices, route controls, system status indicators and alarms and a management information system; this equipment was all estimated as being in "fair" to "excellent" condition. The communications subsystem for the commuter rail includes telephones, cable carrier, call boxes, central station equipment, vehicle-borne units, power supervision links, CCTV cameras and monitors and PA units. The equipment ranges in age from 3 to 57 years; all were evaluated as being in "poor" to "good" condition. The supervisory and controls subsystem includes traction power and facilities supervision units; these were estimated as being in "fair" to "good" condition. In summary, the evaluation for the system-wide controls for the commuter rail system indicates a "fair" to "good" condition.

- NORTHERN NEW JERSEY

The rapid rail system train control subsystem primarily consists of dispatching devices, wayside ATP equipment, route control equipment, station graphic control equipment, and a central automatic train protection subsystem. The train protection component, track circuits and associated insulated joints and impedance bonds are "good", and wayside signals, train stop, and interlocking equipment are "excellent". The signal equipment housings are "good" to "excellent". The train supervision/schedule control components vary in condition from "fair" to "good". The station graphics/sign controls are all "good", and route control/interlocking control provisions are "good" to "excellent". The communications subsystem consists of PA equipment, CCTV recording units, telephones, call boxes, and other types of equipment. The internal television provisions are "good" except for the Centrax System which is in "fair" condition. The radio system is generally "good", except for the base station equipment, which is in "fair" condition. A large portion of the in-tunnel antenna system is twin lead and is considered to be technically obsolete. The vehicle-borne PA equipment is "fair" to "good"; all other equipment is "good". All CCTV equipment is "good" and the data links, many of which are leased telephone lines, are in "good" condition. All recording devices are "good" except for the video recorders which are in "fair" condition. The supervisory and control subsystem consists of traction power and facilities supervision equipment. The traction power monitoring and control system is in generally "fair" condition; the facilities monitoring and control system is in generally "good" condition. However, the equipment used to monitor the fare collection system is also considered to be cumbersome. The summary evaluation indicates an overall "fair" condition for the system-wide controls element.

The light rail system train control subsystem primarily consists of wayside train protection, which is about 49 years old; it was estimated that this system was in "good" condition. The communications subsystem primarily consists of radios, which were in "poor" condition. The supervisory and control subsystem is approximately 49 years old and was estimated as being in "good" condition. The summary evaluation indicates an overall "fair" condition for the system-wide controls element.

The commuter rail train control subsystem includes wayside and vehicle-borne automatic train protection, train supervision, and vehicle-borne automatic train operation units which were all estimated as being in "fair" to "excellent" condition. The communications subsystem includes data links, telephone systems, cable carrier, central and vehicle-borne radio, antennas and voice recording units. The major components were estimated as being in "fair" to "good" condition. The supervisory and control subsystem includes facilities supervision and traction power supervision units and these were estimated as being in "fair" to "excellent" condition. The summary evaluation indicates an overall "good" condition for the system-wide control element.



New and Old Signals on Catenary Bridge

- SOUTHERN NEW JERSEY

The rapid rail train control system element includes train control equipment, train operations and protection equipment, and train supervision equipment. The car-borne ATC equipment is in "good" condition, however the speed control is unsatisfactory for the 1968 cars; but excellent for the 1980 cars. The door operations are "fair" for both types of cars. The cab signaling equipment is in "good" condition. The central automatic train control equipment is obsolete and is scheduled for upgrading. The wayside automatic train control equipment is in "good" condition. The communications subsystem includes carrier cable and communication equipment which is in "poor" to "fair" condition. The external telephone system is in "poor" condition and the data links vary in condition. The supervisory and control subsystem equipment is in "good" condition with no apparent problems. The summary evaluation indicates a "good" condition.

- PHILADELPHIA

The rapid rail train control subsystem includes dispatching devices, route controls, central train supervision equipment, wayside and vehicle-borne automatic train protection devices, train operation units, schedule controls, and status indicators/alarms; which were all estimated as being in "fair" to "good" condition. The communications subsystem includes cable carrier, data recording units, telephones, wayside/local and vehicle-borne PA units, hand-carried and central/stationary radio units, and voice recording units; this equipment was all estimated as being in "fair" to "excellent" condition. The supervisory and control subsystem for the rapid rail system includes traction power supervision and facilities supervision equipment which were estimated as being in "good" to "excellent" condition. The summary evaluation indicates an overall estimate of "good" condition.

The light rail train control subsystem includes wayside automatic train protection and route control units; these were all estimated as being in "good" to "excellent" condition. The communications subsystem includes call boxes, vehicle-borne and wayside/local PA units, radios, antennas, power supervision data links, CCTV, and voice recording units; which were all estimated as being in "fair" to "excellent" condition. The supervisory and control subsystem includes traction power and facilities supervision units and were all estimated as being in "good" condition. The overall evaluation for the system-wide controls for the light rail system was "good".

The train control subsystem for commuter rail includes wayside and vehicle-borne automatic train protection units, and train supervision equipment, all of which were estimated as being in "poor" to "good" condition. The communications subsystem includes train control links, power supervision links, telephones, PA systems, vehicle-borne and hand-carried radio units as well as voice recording units; these were all estimated as being in "poor" to "excellent" condition. The supervisory and control subsystem includes traction power supervision and status board/displays which were estimated as being in "fair" to "excellent" condition. The summary evaluation indicates an overall "fair" condition.

- PITTSBURGH

The train control subsystem for the light rail system primarily consists of wayside train protection units, which are 58 years old and it was estimated that these were in "poor" condition. The communications subsystem includes radios and recording devices which are approximately 17 years old and it was estimated that these were in "fair" condition. The supervisory and control subsystem is manual. The summary evaluation indicates an overall estimate of "fair" condition.

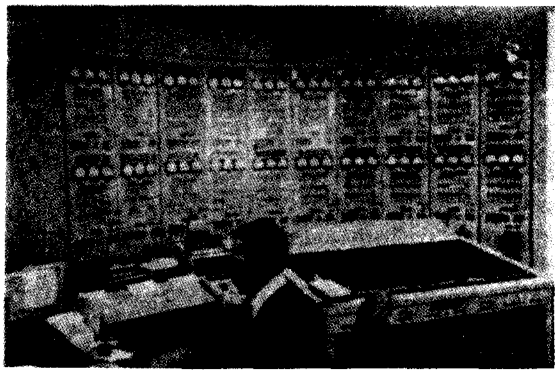
The train control subsystem for the commuter rail system consists primarily of train protection units, which are about 21 years old and are in "good" condition. The communications subsystem includes radios, which are about 10 years old and these are also in "good" condition. No supervisory control related equipment is directly associated with this commuter service, although the Baltimore & Ohio and Pittsburgh & Lake Erie have some equipment for general use on the lines which primarily carry freight. The overall evaluation for the commuter rail system was estimated as being "good".

- WASHINGTON, DC

The train control subsystem for rapid rail includes dispatching devices, scheduling controls train supervision equipment and wayside and vehicle-borne automatic train operation and train protection equipment; these were estimated as being in "bad" to "good" condition. The communication subsystem includes telephones, radios, CCTV, cable carrier, PA units, and voice recording units and these were estimated as being in "fair" to "excellent" condition. The supervisory and control subsystem includes traction power facilities supervision and control equipment; these were estimated as being in "good" condition. The summary evaluation for the rapid rail system for system-wide controls was estimated as "good".

- CHICAGO

The train control subsystem for rapid rail includes dispatching devices, wayside and vehicle-borne automatic train protection units, dispatching units, route controls and system status indicators/alarms; these equipments were all estimated as being in "good" condition. The rapid rail communications subsystem includes telephones, data links, cable carrier, vehicle-borne and wayside/local PA units, radios and recording units; which were all estimated as being in "good" to "excellent" condition. The supervisory and control subsystem primarily consists of traction power supervision controls and displays which are approximately 14 years old and in "good" condition.



Control Room

The commuter rail train control subsystem includes wayside and vehicle-borne automatic train protection, train supervision, route controls, and vehicle-borne automatic train operation equipment; the major components were estimated as being in "poor" to "excellent" condition. The communications subsystem includes cable carrier, power supervision links, radios, and other equipment, which were all estimated as being in "poor" to "good" condition. The supervisory and control subsystem includes traction power and facilities supervision equipment, which were in "fair" to "excellent" condition. The summary evaluation indicates an overall estimate of "fair" condition.

Dwarf Signal

- CLEVELAND

The train control subsystem for rapid rail includes wayside and vehicle-borne automatic train protection units, and train supervision equipment; these were all estimated as being in "fair" to "good" condition. The communications subsystem includes power supervision links, train control links, telephones, and radios; these were all estimated as being in "poor" to "good" condition. The supervisory and control subsystem includes only traction power supervision equipment; this was estimated as being in "good" condition. The overall evaluation of the system-wide controls for the rapid rail system was "fair".

The light rail train control subsystem includes wayside automatic train protection units and train supervision equipment; these were estimated as being in "fair" to "good" condition. The communications subsystem includes telephone, PA, and radio units, all of which were in "good" to "excellent" condition. The supervisory and control subsystem includes only traction power supervision units which were estimated as being in "good" condition. The overall estimate for the system-wide controls was "good".

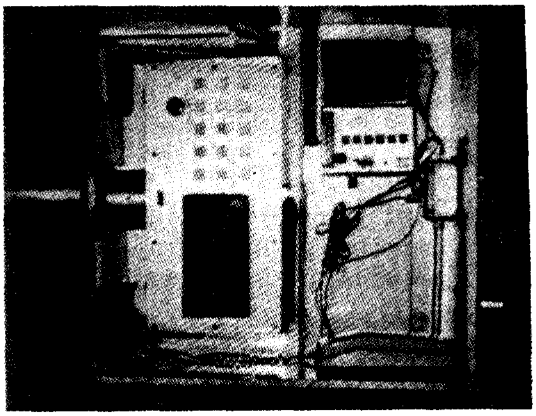
- ATLANTA

The train control subsystem for the rapid rail system includes train operations equipment, wayside and vehicle-borne automatic train protection equipment, route controls, and system status indicators/alarms; these were all estimated as being in "good" to "excellent" condition. The communications subsystem includes cable carrier, telephones, radios, CCTV, and other pieces of equipment which were all estimated as being in "good" to "excellent" condition. The supervisory and control subsystem includes traction power and facilities supervision equipment which were all estimated as being in "good" condition. The summary evaluation for system-wide controls indicates an overall "good" condition.

- SAN FRANCISCO

The train control subsystem for the rapid rail system includes train supervision units, wayside and vehicle-borne automatic train operation and train protection equipment, which was estimated as being in "fair" to "good" condition. The communications subsystem includes cable carrier, telephones, PA units, radios, CCTV, and voice recording units; these were all estimated as being in "fair" to "good" condition. The supervisory and control subsystem includes supervision and control units for traction power and facilities; these were estimated as being in "good" condition. The overall estimate for the system-wide controls for the rapid rail system was "fair" to "good".

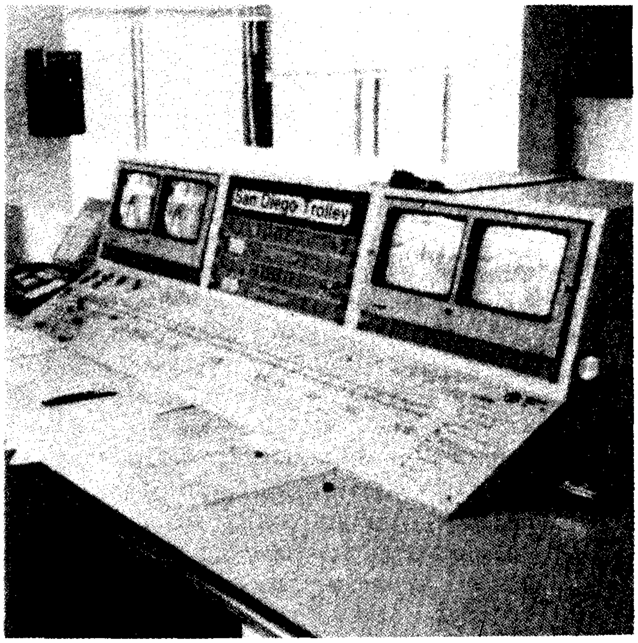
The light rail train control subsystem includes wayside and vehicle-borne automatic train operation units, wayside and vehicle-borne automatic train protection units, and train supervision equipment; these were estimated as being in "good" to "excellent" condition. The communications subsystem includes vehicle-borne and wayside/local PA units, radios, facilities supervision links, cameras, telephones, CCTV, and other equipment which were all estimated as being in "fair" to "excellent" condition. The supervisory and control subsystem includes facilities and traction power control and supervision equipment, which were estimated as being in "fair" to "excellent" condition. The overall estimate of the light rail system-wide controls system element was "good".



Route Control Entry Station

- SAN DIEGO

The train control subsystem for the light rail system includes wayside automatic train protection units, which were estimated as being in "good" condition. The communications subsystem includes telephones, PA units, radio system, CCTV; all these were estimated as being in "good" condition. The supervisory and control subsystem includes facilities supervision equipment and these were estimated as being in "good" condition. The overall evaluation for the light rail system-wide control system is "good".



Control Center

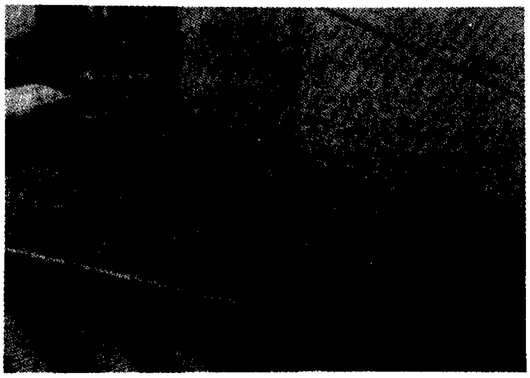
o Station Condition

The condition of the stations for the rail transit systems is provided in Table 3.11. The information in this table presents the areas associated with both stations and station stops in order to illustrate the total magnitude of the condition for this system element. The rapid rail systems have 875 stations; 144 in "poor" condition (mostly in New York City) and 531 in "fair" condition (67 percent of these are in New York City and 20 percent in Chicago). The light rail systems include approximately 86 stations of which 7 are in "poor" condition and 48 are in "fair" condition. The commuter rail systems contains 621 stations of which 6 are in "bad" condition, 116 in "poor" condition and 350 in "fair" condition.

A discussion follows of the station condition in each of the major rail areas, with some emphasis on items of particular concern:

- BOSTON

The rapid rail system has 48 stations; 2 of which are in "poor" condition, 21 are in "fair" condition, and the remainder are in "good" or "excellent" condition. The 2 stations in "poor" condition are both subway stations, approximately 80 years old and contain about 50,000 square feet. The stations in "fair" condition range in age from 32 to 75 years and include at-grade, elevated, and subway stations; they include about 370,000 square feet of area.



Cracked Wall

TABLE 3.11

STATION CONDITION (Thousands of Square Feet)

Major Rail Areas	Rapid Rail						Light Rail						Commuter Rail					
	E	G	F	P	B	T	E	G	F	P	B	T	E	G	F	P	B	T
Boston	99	390	370	50	-	909	48	205	152	-	-	405	14	94	133	36	-	277
New York	-	517	9471	2990	-	12978						NA	269	233	1372	-	-	1874
Northern NJ	-	103	248	-	-	351	-	-	38	50	-	88	8	17	672	478	14	1189
Southern NJ	22	78	79	-	-	179						NA						NA
Philadelphia	500	155	560	25	-	1240	-	98	160	2	-	260	1	20	256	152	16	445
Pittsburgh						NA	1	-	21	-	-	22	-	30	-	-	-	30
Washington, DC	116	1444	-	-	-	1560						NA	7	5	17	5	6	40
Chicago	86	150	1142	176	-	1554						NA	66	306	495	199	9	1075
Cleveland	-	-	89	97	-	186	28	-	22	-	-	50						NA
Atlanta	342	874	-	-	-	1216						NA						NA
New Orleans						NA	-	-	-	-	-	None						NA
San Francisco	-	1298	54	-	-	1352	-	253	-	-	-	253	2	-	47	6	-	55
San Diego						NA	66	-	-	-	-	66						NA
TOTAL	1165	5009	12013	3338	-	21525	143	556	393	52	-	1144	367	705	2992	876	45	4985

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

NA - Not Applicable

The light rail system includes 21 stations, 10 of which are in "fair" condition and 11 in "good" condition. The stations in "fair" condition range in age from 34 to 87 years of age. When station stops are included, 152,000 square feet are in "fair" condition, 205,000 square feet in "good" condition, and 48,000 square feet in "excellent" condition.

The commuter rail system includes 29 stations, 2 of which are in "poor" condition and 15 are in "fair" condition. The stations in "poor" condition range in age from 58 to 75 years. The stations in "fair" condition range in age from 9 to 75 years. When station stops are included, 36,000 square feet are in "poor" condition, 133,000 square feet are in "fair" condition, and the remainder in either "good" or "excellent" condition.

Station

- NEW YORK

The rapid rail systems in New York include 487 stations; 110 are in "poor" condition (about 3.0 million square feet), and 355 are in "fair" condition (about 9.5 million square feet). The stations in "poor" condition range in age from 45 to 66 years and include subway, elevated, and at-grade stations. Contributing to these "poor" conditions are the condition of elevators, escalators, wooden platforms, graphics, graffiti on many station walls and columns, lighting systems, and some hairline spalling in the structures.

Elevated Express Station

The commuter rail systems include 185 stations, 129 which are in "fair" condition. The stations in "fair" condition range in age from 10 to 61 years and include elevated and at-grade stations. Some deterioration of the retaining walls and other concrete surfaces was observed on some of these older stations, resulting in the "fair" condition. When station stops are included, 14,000 square feet are in "bad" condition, 478,000 square feet in "poor" condition, 672,000 square feet in "fair" condition, and the remainder in "good" or "excellent" condition.

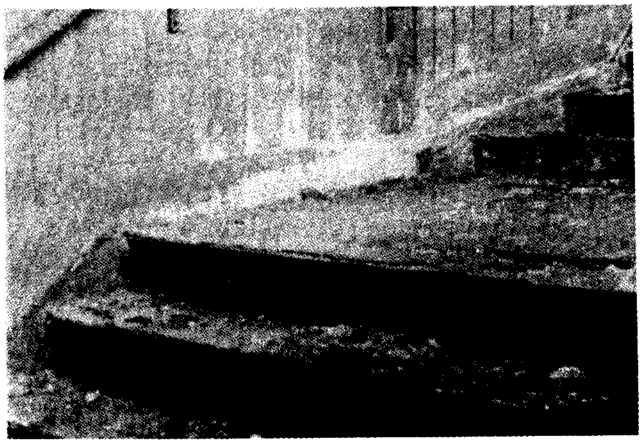
- NORTHERN NEW JERSEY

The rapid rail system has 13 stations and 11 of these are in "fair" condition (248,000 square feet) and the remainder are in "good" condition. Platform floors are cracking, spalling and settling. Blind spots have been created by columns and other objects and the distance from entry to boarding is somewhat excessive. The stairs are badly worn and uneven and have some drainage problems. The handrailing shows signs of wear, corrosion, and weakening at the supports. The escalators are in generally "good" condition. The stations are equipped with system information but lack patron assistance telephones. Some of the station seating should be replaced.

The light rail system includes 9 stations, 4 of which are in "fair" condition and 5 in "poor" condition. The stations in "fair" condition are 49 to 54 years old and are either historic or subway stations. When station stops are added, 50,000 square feet is in "poor" condition, and 38,000 square feet is in "fair" condition Contributing to the "fair" condition are stairs, which are badly worn or uneven and need improvement; escalators in "poor" condition; stair railings at the grade crossing barriers which exhibit substantial wear; concrete platforms showing major deterioration; inadequate station graphics; and no provisions for security. Interior finishes for the subway stations are in "poor" condition and the canopies and structure indicate some corrosion and decay.

Deteriorated Platform

The commuter rail system has 123 stations, 1 of which is in "bad" condition, 54 are in "poor" condition and 66 are in "fair" condition. When station stops are added, 14,000 square feet are in "bad" condition, 478,000 square feet in "poor" condition, 672,000 square feet in "fair" condition, and the remaining 25,000 square feet in "good" or "excellent" condition. The station in "bad" condition is an at-grade station, which is approximately 54 years old. The stations in "poor" condition are all approximately 64 years old and include elevated and at-grade stations. Although some platforms are only experiencing minor spalling and settlement, a few do show signs of major deterioration. Concourse floor areas, occasionally provided with a finished floor material, are below acceptable standards for passenger stations. In many stations, circulation patterns are awkward since direct passage from the concourse area to the platforms are not provided. Some of the stations have stairs, which are in "poor" condition. The lack of slip resistant surfaces and insufficient railings for the elderly and handicapped and the absence of weather protection has aided the deterioration of much of the equipment. The station finishes typically are in "poor" to "fair" condition and require substantial rehabilitation. Interior finishes including brick, concrete block, woodplank, cement plaster, acoustical tile, drywall and plastic laminent, which are in "poor" to "fair" condition.



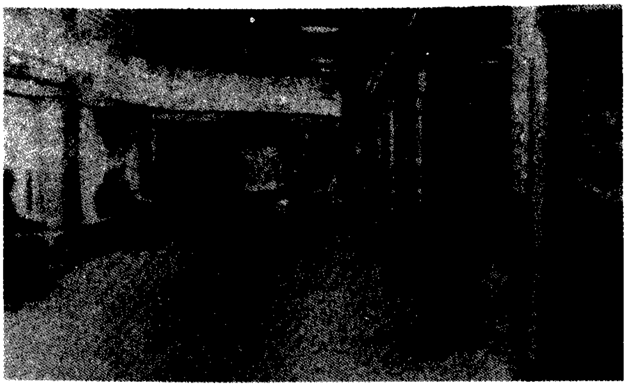
Deterioriated Stairwell

- SOUTHERN NEW JERSEY

The rapid rail system has 13 stations and 5 of these are in "fair" condition, 6 in "good" condition and 2 in "excellent" condition. These 13 stations consist of approximately 179,000 square feet of station area. Some of the stairs are worn or uneven and need improvement. Some hairline cracks were observed on the horizontal circulation systems and spalling and failure of the expansion joints were observed. The fare collection equipment is in "good" condition with the newer equipment much improved since the system was installed 10 years ago. Some water leakage was observed that is due to the failure of the roof membrane. There are hairline cracks in some of the structures and some spalling and deteriorated next to the expansion joints. The mechanical and electrical equipment is in "good" condition but no apparent problems.

- PHILADELPHIA

The rapid rail systems have 53 stations; 2 of which are in "poor" condition (25,000 square feet), 27 in "fair" condition (560,000 square feet), and the remaining 24 stations are in "good" or "excellent" condition. The stations in "poor" condition are both elevated and are 79 years old. The stations in "fair" condition range in age from 33 to 77 years old and include both subway and elevated stations. Typical problems include localized structural problems, deteriorated steps, and graffiti at some stations. The noise level in the stations is also bad with some evidence suggesting that the rail cars are the problem and not the stations.



Rapid Rail Station

The light rail system includes 34 stations, 2 of which are in "poor" condition and the remainder are in "fair" condition. The total area for stations and station stops is 2,000 square feet in "poor" condition, 160,000 square feet in "fair" condition and 98,000 square feet in "good" condition. The light rail stations in "poor" condition are both at-grade stations and are approximately 59 years old. The other light rail stations range in age from 33 to 58 years and are in "fair" condition.

The commuter rail systems have approximately 106 stations; 2 of which are in "bad" condition, 41 in "poor" condition and 58 in "fair" condition. The total area associated with both stations and station stops is 16,000 square feet in "bad" condition, 152,000 square feet in "poor" condition, 256,000 square feet in"fair" condition and the remaining 21,000 square feet in "good" or "excellent" condition. The stations in "bad" condition are elevated stations, that are approximately 64 years old. The stations in "poor" condition range in age from 1 to 74 years. Most of the older stations are in "poor" to "bad" condition, with leaking wood members, which are rotting. Some platforms have handicapped access, but most do not. Many platforms also have poor circulation. The graphics are poor or nonexistent at many of the stations and parking is often inadequate or altogether absent. Most station finishes are "bad" and most of the mechanical and electrical equipment should be replaced.

- PITTSBURGH

The light rail system has no stations, but the station stops are in "fair" condition (19,000 square feet).

The commuter rail system has 5 stations, all of which are in "good" to "excellent" condition. These stations are all approximately 3 years old.

- WASHINGTON, DC

The rapid rail system has 48 stations, 44 of which are in "good" condition (about 1.4 million square feet) and 4 in "excellent" condition.

The commuter rail system has approximately 13 stations, 2 of which are in "bad" condition, 6 in "fair" condition and the remainder are in either "good" or "excellent" condition. The total area associated with both stations and station stops is 6,000 square feet in "bad" condition, 5,000 square feet in "poor" condition, 17,000 square feet in "fair" condition, and the remainder is in "good" or "excellent" condition. The 2 stations in "bad" condition range in age from 44 to 58 years and are being abandoned. The stations in "fair" condition range in age from 4 to 56 years.

Commuter Rail Station

- CHICAGO

The rapid rail system has 144 stations; 17 of which are in "poor" condition (176,000 square feet) and 106 are in "fair" condition (about 1.1 million square feet). The stations in "poor" condition range in age from 81 to 89 years and include a historic station, elevated stations and at-grade stations. The most important problem is the water damage to other subsystems, including some of the structural elements. Most of the corrugated iron roofing covering the platforms are beyond their useful lives. Water leaks through the roofing are corroding the stair support and creating potentially hazardous conditions. Another set of failures has been observed at the corrugated wind screens that envelope the loop stations; the rivet holes of these stations display cracks and general deterioration.

The commuter rail systems have 160 stations, 1 of which is in "bad" condition, 37 are in "poor" condition, and 63 are in "fair" condition. The station in "bad" condition is an elevated station that is approximately 50 years old and is being abandoned. The stations in "poor" condition range in age from 24 to 59 years. When both stations and station stops are included, 9,000 square feet is in "bad" condition, 199,000 square feet in "poor" condition, 495,000 square feet in "fair" condition, and the remainder in "good" or "excellent" condition.

Commuter Rail Station

- CLEVELAND

The rapid rail system has 18 stations; 13 of which are in "poor" condition (97,000 square feet), and 5 in "fair" condition (89,000 square feet). The stations in "poor" condition are at-grade stations, which are approximately 24 years old. These stations exhibit a wide range of deterioration and vandalism is a major problem, especially to the canopies over stairs at several of the stations.

The light rail system has no stations but the station stops are "fair" (22,000 square feet) and "excellent" (28,000 square feet) condition.

- ATLANTA

The rapid rail system contains 20 stations, all of which are relatively new and in "good" to "excellent" condition (1.2 million square feet).

- NEW ORLEANS

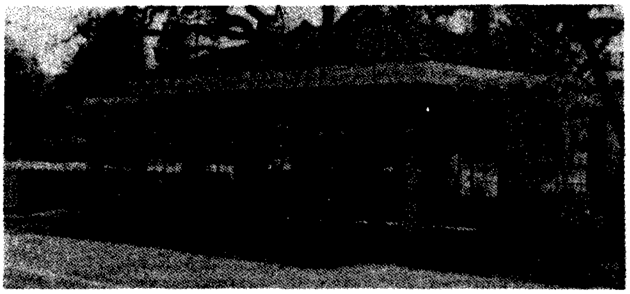
The light rail system has no stations or physically defined station stops (stops at street corners, etc.).

- SAN FRANCISCO

The rapid rail system includes 34 stations, 1 of which is in "fair" condition (54,000 square feet) and the remainder are in "good" condition (about 1.3 million square feet). The one station in "fair" condition is a subway station, which is approximately 12 years old. The other stations are also 12 years old but have not had as much water intrusion and the escalators are in slightly better condition.

The light rail system has 9 stations, all of which are in "good" condition. The total area of both stations and station stops is 253,000 square feet in "good" condition.

The commuter rail system includes 13 stations, all of which were estimated as being in "fair" condition. This commuter rail system has 2 historic stations, which range in age from 49 to 117 years. However, the horizontal circulation is adequate and most of the interior/exterior finishes are in a "good" condition. The total area, of both stations and station stops is 6,000 square feet in "poor" condition, 47,000 square feet in "fair" condition and 2,000 square feet in "excellent" condition.



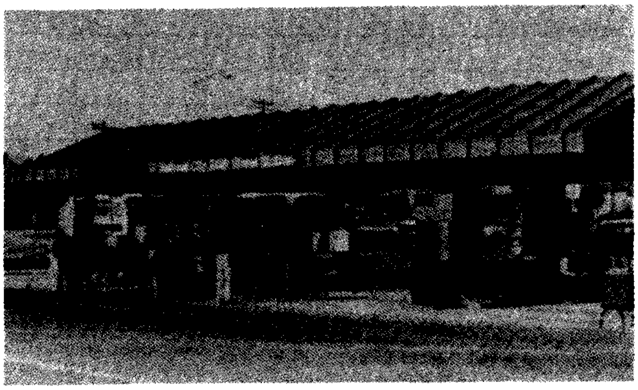
Commuter Rail Stop

- SAN DIEGO

The San Diego stations are new and all are in "excellent" condition. The total area of both stations and station stops is 66,000 square feet in "excellent" condition.

o Structures and Facilities -Bridge Condition

The condition of the bridges on the rail transit systems is provided in Tables 3.12 and 3.13. The rapid rail systems have approximately 1.8 million square feet of bridges (excluding elevated railways). Of this, 1 percent is in "bad" condition (mostly in New York City), 19 percent is in "poor" condition (mostly in New York, Chicago and Cleveland), and 32 percent is in "fair" condition. Elevated railway bridges (rapid rail) include approximately 1.1 million lineal feet of which 83 percent is in "fair" condition (mostly in Chicago and New York) and the remainder is in "good" or "excellent" condition. The light rail systems have 380,000 square feet of bridges (excluding elevated railways). Of this, 3 percent is in "bad" condition (mostly Boston), 16 percent is in "poor" condition (mostly in Cleveland), and 41 percent is in "fair" condition (mostly in Boston and Philadelphia). The elevated railway bridges (light rail) include 6,000 lineal feet of which 67 percent is in "poor" condition (Philadelphia) and 33 percent is in "fair" or "good" condition. The commuter rail systems have approximately 9.1 million square feet of bridges (excluding elevated railways). Of this, less than 1 percent is in "bad" condition, 14 percent is in "poor" condition (mostly in New York, Northern New Jersey, Philadelphia and Chicago), and 55 percent is in "fair" condition (mostly in New York, Northern New Jersey, Philadelphia and Chicago). The elevated railway bridges (commuter rail) include 93,000 lineal feet of



Light Rail Stop

TABLE 3.12

BRIDGE CONDITION (EXCLUDING ELEVATED RAILWAYS)

(Thousands of Square Feet)

Major Rail Areas	Rapid Rail						Light Rail						Commuter Rail					
	E	G	F	P	B	T	E	G	F	P	B	T	E	G	F	P	B	T
Boston	37	211	49	-	-	297	-	3	52	10	9	74	-	93	272	40	1	406
New York	-	211	133	70	18	432						NA	169	1110	1592	526	15	3412
Northern NJ	-	-	66	-	5	71	-	2	2	-	-	4	8	173	982	321	-	1484
Southern NJ	-	16	28	25	-	69						NA						NA
Philadelphia	-	-	14	-	-	14	-	27	50	10	3	90	-	62	662	304	25	1053
Pittsburgh						NA	-	6	14	1	-	21	-	30	6	-	-	36
Washington, DC	49	76	8	-	-	133						NA						NA
Chicago	-	26	203	54	-	283						NA	82	998	1501	171	-	2752
Cleveland	-	29	78	200	-	307	-	-	39	39	-	78						NA
Atlanta	21	3	-	-	-	24						NA						NA
New Orleans						NA	-	-	-	-	-	None						NA
San Francisco	206	-	-	-	-	206	-	-	-	-	-	None						NA
San Diego						NA	25	88	-	-	-	113						NA
TOTAL	313	572	579	349	23	1836	25	126	157	60	12	380	259	2466	5015	1362	41	9143

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

NA - Not Applicable

TABLE 3.13

BRIDGE CONDITION (Elevated Railways)

(Thousands of Lineal Feet)

Major Rail Areas	Rapid Rail						Light Rail						Commuter Rail					
	E	G	F	P	B	T	E	G	F	P	B	T	E	G	F	P	B	T
Boston	-	2	24	-	-	26	-	-	1	-	-	1	-	-	1	-	1	2
New York	-	-	340	-	-	340						NA	23	16	39	-	-	78
Northern NJ	-	-	2	-	-	2	-	-	-	-	-	None	-	-	5	-	-	5
Southern NJ	-	5	1	-	-	6						NA						NA
Philadelphia	-	-	52	-	-	52	-	1	-	4	-	5	-	1	-	7	-	8
Pittsburgh						NA	-	-	-	-	-	None	-	-	-	-	-	None
Washington, DC	30	-	-	-	-	30						NA						NA
Chicago	-	6	469	-	-	475						NA	-	-	-	-	-	None
Cleveland	-	-	3	-	-	3	-	-	-	-	-	None						NA
Atlanta	19	-	-	-	-	19						NA						NA
New Orleans						NA	-	-	-	-	-	None						NA
San Francisco	123	-	-	-	-	123	-	-	-	-	-	None						NA
San Diego						NA	-	-	-	-	-	None						NA
TOTAL	172	13	891	-	-	1076	-	1	1	4	-	6	23	17	45	7	1	93

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

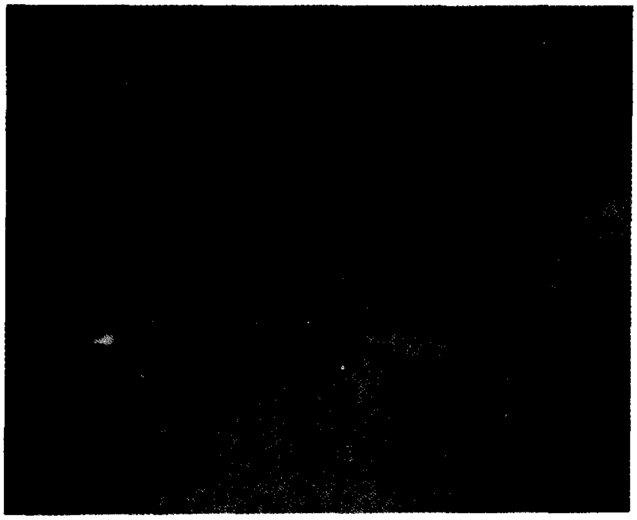
NA - Not Applicable

which 9 percent is in "bad" or "poor" condition (mostly in Philadelphia) and 48 percent is in "fair" condition (mostly in New York). The majority of the bridges and elevated structures consist of deck and through plate girder type bridges (both ballasted and open deck) supported by built-up steel columns and gravity abutments. Other types of bridges that were encountered included arches (brick, stone and concrete), trusses (deck and through types), movable (lift, swing, and scissor), trestle (steel and wood) and concrete slab. Some of the metal construction was wrought iron rather than steel.

A discussion of the condition of these bridges in each of the major rail areas follows, with some emphasis on items of particular concern:

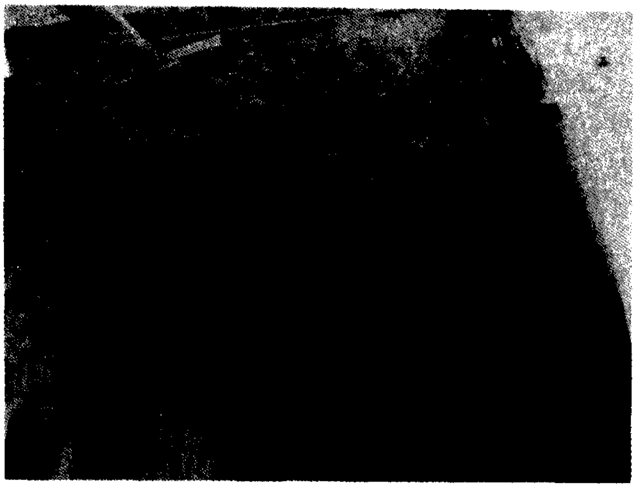
- BOSTON

The rapid rail system includes 26,000 lineal feet of elevated railway bridge (24,000 lineal feet in "fair" condition) and 297,000 square feet of other types of bridges (49,000 square feet in "fair" condition). The bridges in "fair" condition range in age from 54 to 64 years.



Cracks in Beams and Columns

The light rail system contains 1,000 lineal feet of elevated railway and 74,000 square feet of other types of bridges. The bridges in "bad" condition range in age from 65 to 100 years and contain 9,000 square feet. The bridges in "poor" condition contain 10,000 square feet and the bridges in "fair" condition include 1,000 lineal feet of elevated railway and 52,000 square feet of other types of bridges.



Heavy Spalling

The commuter rail system contains 2,000 lineal feet of elevated bridges and 406,000 square feet of other types of bridges. The bridges in "bad" condition range from 47 to 71 years of age and consist of 1,000 lineal feet of elevated railway and 1,000 square feet of other types of bridges. The bridges in "poor" condition were all approximately 74 years old and included 40,000 square feet of both girder and arch type bridges. The bridges in "fair" condition include 1,000 lineal feet of elevated bridges and 272,000 square feet of other types of bridges.

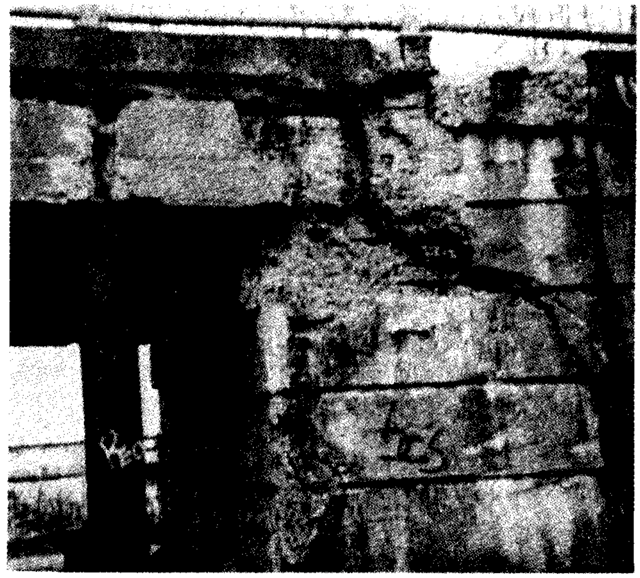
Condition of Concrete and Steel Members

- NEW YORK

The rapid rail system has 340,000 lineal feet of elevated bridges and 432,000 square feet of other types of bridges. The "bad" bridges range in age from 51 to 60 years, and include 18,000 square feet of deck girder bridges as well as highway bridges. The bridges in "poor" condition are all highway bridges and contain 70,000 square feet; they are approximately 50 years old. The bridges in "fair" condition range from 44 to 67 years of age and include 340,000 lineal feet of elevated railways and 133,000 square feet or railway and highway bridges.

The commuter rail systems contain 78,000 lineal feet of elevated bridges and 3.4 million square feet of other types of bridges. The bridges in "bad" condition (15,000 square feet) are through girder type bridges and are approximately 71 years old. The bridges in "poor" condition range in age from 60 to 91 years and include 526,000 square feet of railway bridges, deck girder bridges, through girder bridges, and multigirder bridges.

The bridges in "fair" condition range in age from 50 to 100 years and include railway bridges and highway bridges.



Cracked and Failed Abutment and Facia

- NORTHERN NEW JERSEY

The rapid rail system has 2,000 lineal feet of elevated railway and 71,000 square feet of other types of bridges. The railroad bridges including 2 elevated viaducts, 2 through girder and

Through Truss and Through Girder Bridge

movable bridges are in "fair" condition. The highway bridges passing over the PATH system are in "poor" to "fair" condition. These bridges are all approximately 60 years old.

The light rail system has 4,000 square feet of bridges; 2,000 square feet in "fair" condition and 2,000 square feet in "good" condition. These bridges are approximately 43 years old and contain 2,000 square feet of area.

Column Corrosion at Inert Slab

The commuter rail system has 5,000 lineal feet of elevated bridges and 1.5 million square feet of other types of bridges. 321,000 square feet of bridges are in "poor" condition. Bridges in "fair" condition include 5,000 lineal feet of elevated railway and 982,000 square feet of other types of bridges. The bridges in "poor" condition range in age from 60 to 70 years and include deck girder bridges, through girder bridges, multi-girder bridges and truss bridges. The bridges in "fair" condition range in age from 60 to 85 years and include all types of bridges.

Crack in Bridge Pedestal

- SOUTHERN NEW JERSEY

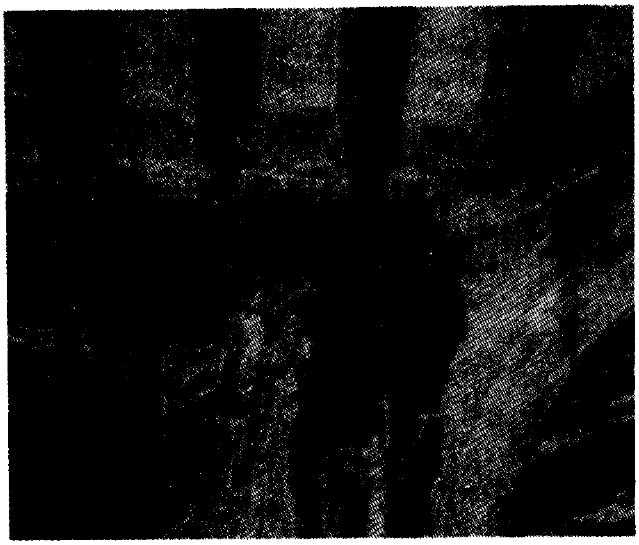
The rapid rail system has approximately 6,000 lineal feet of elevated railway and 69,000 square feet of other types of bridges. 25,000 square feet of bridges are in "poor" condition. The bridges in "fair" condition include 1,000 lineal feet of elevated bridges and 28,000 square feet of other types.

- PHILADELPHIA

The rapid rail system has 52,000 lineal feet of elevated bridges and 14,000 square feet of other types of bridges, all of which are in "fair" condition. The bridges range in age from 23 to 73 years and include all types of bridges.

The light rail system consists of 5,000 lineal feet of elevated bridges and 90,000 square feet of other types of bridges. The "bad" bridge is approximately 79 years old and is a highway bridge (3,000 square feet). The bridges in "poor" condition range in age from 73 to 79 years and include 4,000 lineal feet of elevated railways, and 10,000 square feet of railway bridges.

The commuter rail system includes 8,000 lineal feet of elevated bridges and 1,053 square feet of other types of bridges. The "bad" bridges are through girder type bridges and are approximately 70 years old (25,000 square feet). The "poor" bridges include 7,000 lineal feet of elevated bridges and 304,000 square feet of other types of bridges. These bridges range from 60 to 100 years in age and include through girder type, trestles, elevated viaducts and deck girder bridges. 662,000 square feet of bridges are in "fair" condition.



Spalled Concrete

- PITTSBURGH

The light rail system contains 21,000 square feet of bridges. The bridge in "poor" condition is a deck girder type bridge and is approximately 81 years old; it contains 1,000 square feet of area. The bridges in "fair" condition range from 81 to 114 years of age and are primarily deck girder type bridges (14,000 square feet).

The commuter rail system contains 36,000 square feet of bridges. The 2 bridges in "fair" condition range in age from 53 to 72 years and are primarily deck girder bridges (6,000 square feet). The bridges in "good" condition range in age from 16 to 64 years and include deck girder type bridges, multi-girder type bridges, and through truss bridges.

- WASHINGTON, DC

The rapid rail system has 30,000 lineal feet of elevated bridges (all in "excellent" condition) and 133,000 square feet of other types bridges. The bridges in "fair" condition contain 8,000 square feet and are through girder type brides; they are approximately 70 years old. The other bridges are approximately 6 years old and in "good" or "excellent" condition.

The commuter rail bridges are not presently maintained by the Maryland Department of Transportation and were not inspected.

- CHICAGO

The rapid rail system contains 475,000 lineal feet of elevated bridges and 283,000 square feet of other types of bridges. The bridges in "poor" condition range in age from 69 to 92 years and contain 54,000 square feet. The bridges in "fair" condition range in age from 14 to 90 years and include 469,000 lineal feet of elevated railway and 203,000 square feet of other types of bridges.

The commuter rail systems contain approximately 2.7 million square feet of bridges. The bridges in "poor" condition range in age from 67 to 100 years and contain 171,000 square feet. The bridges in "fair" condition contain 1,501 square feet.

Spalled Concrete

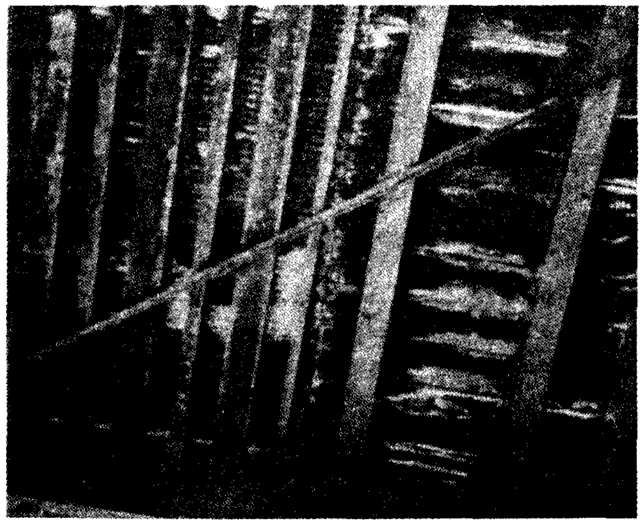
- CLEVELAND

The rapid rail system contains 3,000 lineal feet of elevated bridges and 307,000 square feet of other types of bridges. The bridges in "poor" condition range in age from 53 to 69 years and contain 200,000 square feet. The bridges in "fair" condition include 3,000 lineal feet of elevated bridges and 78,000 square feet of other types of bridges.

The light rail system contains 78,000 square feet of bridges. The bridges in "poor" condition contain 39,000 square feet of area; as do the bridges in "fair" condition.

- ATLANTA

The rapid rail system has 19,000 lineal feet of elevated bridges and 24,000 square feet of other types of bridges, all of which are only 4 to 5 years old and in either "good" or "excellent" condition.



Corroded Metal Deck

- SAN FRANCISCO

The rapid rail system contains 123,000 lineal feet of elevated railways and 206,000 square feet of other types of bridges, all of which are about 15 years old and in "excellent condition.

- SAN DIEGO

The light rail system has 113,000 square feet of bridges, all of which are in either "good" or "excellent" condition. All of these bridges were rehabilitated or constructed in 1981.

o Structures and Facilities -Tunnel Condition

The condition of the tunnels for the rail transit systems is provided in Table 3.14. The rapid rail systems have approximately 291 miles of tunnel; 11.9 miles of which is in "poor" condition, 140.8 in "fair" condition and the remainder is in either "good" or "excellent" condition. The light rail systems have approximately 11 miles of tunnel; less then 1 mile of which is in either "poor" or "bad" condition

TABLE 3.14

TUNNEL CONDITION (Thousands of Lineal Feet)

Major Rail Areas	Rapid Rail						Light Rail						Commuter Rail					
	E	G	F	P	B	T	E	G	F	P	B	T	E	G	F	P	B	T
Boston	-	-	62	-	-	62	-	12	16	1	1	30	-	2	-	-	-	2
New York	-	62	570	55	-	687						NA	-	-	27	16	-	43
Northern NJ	-	62	10	4	-	76	-	-	7	-	-	7	-	-	-	9	-	9
Southern NJ	-	1	24	3	-	28						NA						NA
Philadelphia	-	-	88	-	-	88	-	-	-	-	-	None	-	-	13	-	-	13
Pittsburgh						NA	-	-	-	-	-	None	-	-	-	-	-	None
Washington, DC	-	90	-	-	-	90						NA						NA
Chicago	-	111	-	-	-	111						NA	-	1	-	-	-	1
Cleveland	-	4	-	1	-	5	-	-	-	-	-	None						NA
Atlanta	1	27	-	-	-	28						NA						NA
New Orleans						NA	-	-	-	-	-	None						NA
San Francisco	175	187	-	-	-	362	-	19	3	-	-	22						NA
San Diego						NA	-	-	-	-	-	None						NA
TOTAL	176	544	754	63	-	1537	-	31	26	1	1	59	-	3	40	25	-	68

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

NA - Not Applicable

and 4.9 is in "fair" condition. The commuter rail systems have 13 miles of tunnel; 4.7 miles of which is in "poor" condition and 7.6 miles is in "fair" condition.

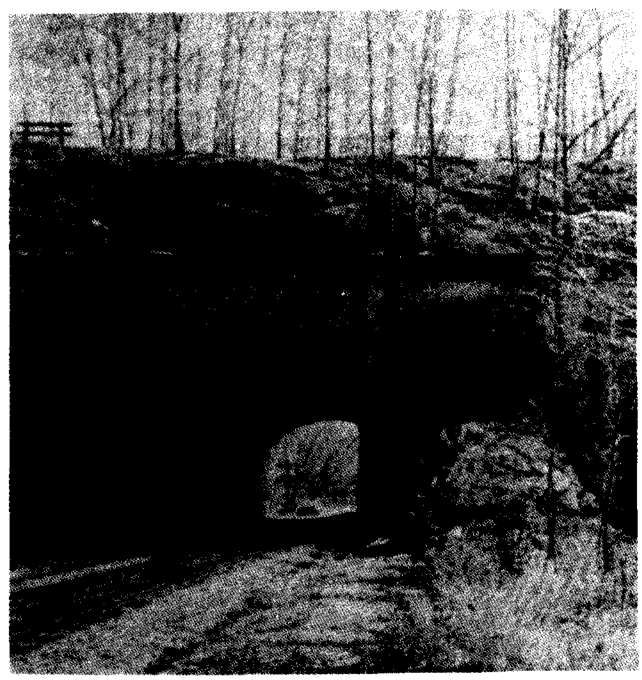
A discussion of the tunnel condition in each of the major rail areas follows, with some emphasis on items of particular concern:

- BOSTON

The rapid rail system contains approximately 62,000 lineal feet of tunnels, all of which is in "fair" condition. These tunnels are approximately 69 years old but still in at least "fair" condition.

The light rail system contains approximately 30,000 lineal feet of tunnel, some of which is in "poor" and "bad" condition, but most is in "fair" and "good" condition. The tunnels in "bad" condition are nearly 90 years old and the tunnels in "poor" condition are approximately 70 years old.

The commuter rail system has approximately 2,000 lineal feet of tunnel, which is 19 years old and in "good" condition.



Concrete Arch Tunnel

- NEW YORK

The rapid rail system contains approximately 687,000 lineal feet of tunnel; 55,000 lineal feet of which is in "poor" condition and nearly 570,000 lineal feet is in "fair" condition. The tunnels in "poor" condition range in age from 65 to 100 years. The tunnels in "fair" condition range in age from 62 to 90 years.

The commuter rail systems contain approximately 43,000 lineal feet of tunnel; 16,000 lineal feet of which is in "poor" condition and 27,000 lineal feet in "fair" condition. The tunnels in "poor" condition are cut-and-cover type tunnels and are approximately 71 years old. Other tunnels are all short tunnels and are also about 71 years old.

- NORTHERN NEW JERSEY

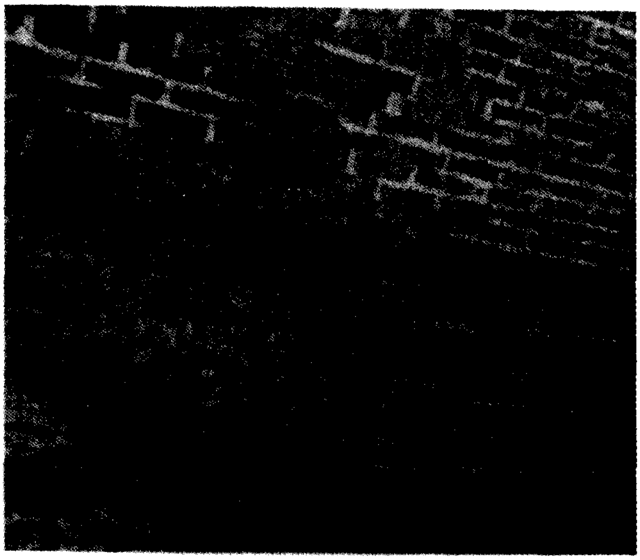
The rapid rail system has 76,000 lineal feet of tunnel and approximately 82 percent of it is in "good" condition with the remainder being in either "poor" or "fair" condition. these shorter sections of tunnel that are in "poor" to "fair" condition are primarily connecting tunnels to the rapid rail line.

The light rail system contains approximately 7,000 lineal feet of tunnel, all of which is in "fair" condition. These tunnels are approximately 43 years old.

The commuter rail system contains approximately 9,000 lineal feet of tunnel, all of which is in "poor" condition and approximately 90 years old.

- SOUTHERN NEW JERSEY

The rapid rail system has 28,000 lineal feet of tunnel and 86 percent is in "fair" condition with the remainder being in "poor" or "good" condition. The tunnel in "poor" condition is between 13th and 16th Street.



Brick Tunnel

- PHILADELPHIA

The rapid rail system contains 88,000 lineal feet of tunnel in "fair" condition. The tunnels range in age from 56 to 73 years.

The commuter rail system has approximately 13,000 lineal feet of tunnel, all of which is in "fair" condition. These tunnels are about 50 years old.

- WASHINGTON, DC

The rapid rail system contains approximately 90,000 lineal feet of tunnel, all of which is in "good" condition. These tunnels are all approximately 10 years old.

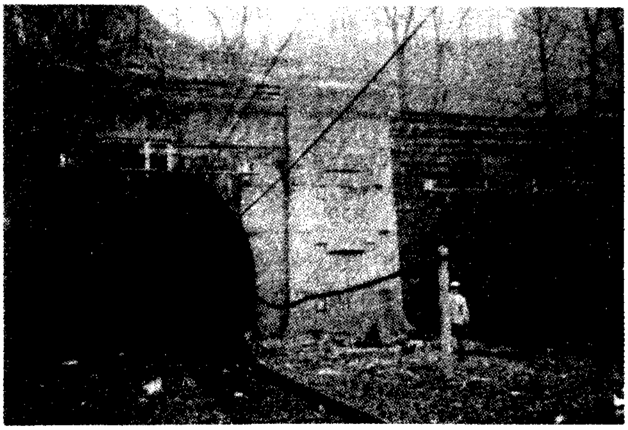
- CHICAGO

The rapid rail system contains approximately 111,000 lineal feet of tunnel, all of which is in "good" condition. These tunnels range in age from 13 to 41 years.

The commuter rail system contains less than 1 mile of tunnel, all of which is in "good" condition.

- CLEVELAND

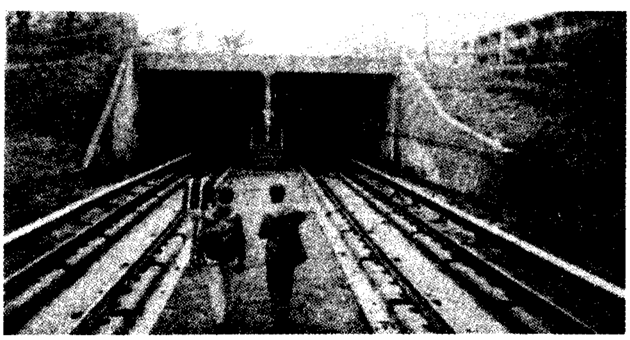
The rapid rail system contains approximately 5,000 lineal feet of tunnel, 1,000 lineal feet in "poor" condition and 4,000 lineal feet in "good" condition. This tunnel is approximately 53 years old.



New Concrete Arch Tunnel and Old Stone Arch Tunnel

- ATLANTA

The rapid rail system contains about 28,000 lineal feet of tunnel, all of which is in either "good" or "excellent" condition. These tunnels are approximately 5 years old.

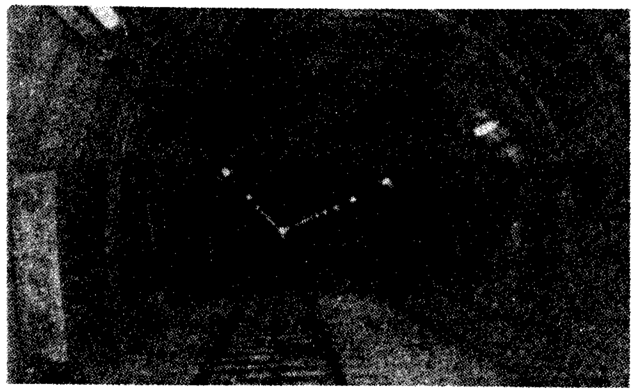


Cut and Cover Tunnel

- SAN FRANCISCO

The rapid rail system contains 362,000 lineal feet of tunnel, all of which is in either "good" or "excellent" condition. The tunnels are all approximately 15 years old.

The light rail system contains about 22,000 lineal feet of tunnel, all of which is in either "fair" or "good" condition. The tunnel in "fair" condition is approximately 60 years old and the other tunnels range in age from 10 to 60 years.



MUNI Sunset Tunnel

o Maintenance Facility Building Condition

The maintenance facilities include general administrative, carhouse, carshop, combination carhouse and carshop, maintenance-of-way, transportation, carwash, and blowdown buildings. Although all of these buildings were inspected, the condition of only the major buildings of the rail transit systems is provided in Table 3.15. The rapid rail systems have approximately 102 major maintenance facility buildings (about 5.4 million square feet) and 3 of these are in "bad" condition, 52 in "poor" condition and 17 in "fair" condition. The light rail systems

TABLE 3.15

MAINTENANCE FACILITY BUILDING CONDITION (Thousands of Square Feet)

Major Rail Areas	Rapid Rail						Light Rail						Commuter Rail					
	E	G	F	P	B	T	E	G	F	P	B	T	E	G	F	P	B	T
Boston	-	352	53	-	2	407	-	130	61	-	-	191	-	-	-	-	166	166
New York	-	32	-	2880	20	2932						NA	44	-	-	1161	44	1249
Northern NJ	-	-	60	-	82	142	-	8	-	-	-	8	-	6	-	173	-	179
Southern NJ	-	106	-	-	-	106						NA						NA
Philadelphia	-	-	303	40	-	343	-	45	64	32	28	169	-	-	43	-	33	76
Pittsburgh						NA	31	-	-	-	-	31						NA
Washington, DC	-	151	186	-	-	337						NA						NA
Chicago	-	41	287	93	-	421						NA	-	518	35	279	-	832
Cleveland	242	1	40	-	-	283	-	-	-	-	-	None						NA
Atlanta	-	226	-	-	-	226						NA						NA
New Orleans						NA	-	-	103	-	-	103						NA
San Francisco	8	170	-	-	-	178	-	230	-	-	-	230						NA
San Diego						NA	15	-	-	-	-	15						NA
TOTAL	250	1079	929	3013	104	5375	46	413	228	32	28	747	44	524	78	1613	243	2502

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

NA - Not Applicable

have 16 major maintenance facility buildings (about 750,000 square feet) and 1 of these was estimated as being in "bad" condition, 1 in "poor" condition and 6 in "fair" condition. The commuter rail systems have 35 major maintenance facility buildings (about 2.5 million square feet) and 3 of these were estimated as being in "bad" condition, 26 in "poor" condition and 2 in "fair" condition.

A discussion of the maintenance facility building condition in each of the major rail areas follows, with some emphasis on items of particular concern:

- BOSTON

The rapid rail maintenance facility has 5 major buildings; 1 carhouse, which is 32 years of age and is in "fair" condition, 2 carhouses that are 9 years old and in "good" condition, 1 carshop that is 49 years old and in "good" condition, and a transportation building that is 34 years old and in "bad" condition (2,000 square feet). The older carhouse should have a new roof, blowout facilities, improved lighting and employee facilities.

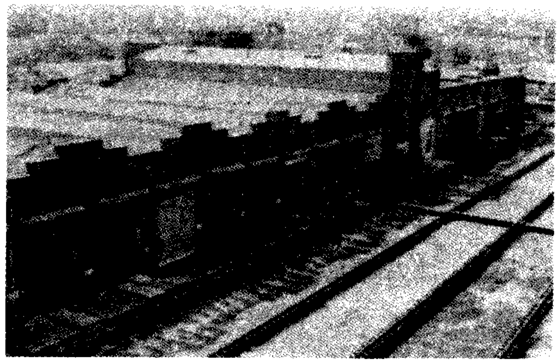
The light rail system has 5 buildings; 1 carhouse that is 54 years old, 1 carhouse that is 49 years old, and 2 carhouses that are 5 to 9 years old in "good" condition (130,000 square feet) and a transportation building that is 55 years old and in "fair" condition. Some of the problems include open joints between the precast panels, which lose heat; roof leaks, a hazardous wheel truing pit, inadequate pit lighting, inoperable overhead lights, and inoperative air stripper and automatic progressive system for the carwasher, and inoperative automatic sanding equipment.

The commuter rail system has 1 major maintenance facility, which is a carshop that is 84 years old, contains 166,000 square feet, and is in "bad" condition. The existing roof structure is not insulated and the roof has numerous leaks. The roof system also has very poor water collection around the permanent building; water drips and freezes in front of the main doors, creating hazardous conditions during the winter months. There is no mechanical ventilation in the existing structure and, with diesel engines running, fumes in the building are concentrated and hazardous to the workmen. The heating and ventilation systems throughout the existing facility are inadequate. The overhead and pit lighting in the existing facilities is in "poor" condition.

- NEW YORK

The rapid rail system has 17 major maintenance facility buildings and 30 maintenance-of-way buildings. The diesel shop is approximately 104 years old and in "bad" condition (20,000 square feet). The car maintenance facilities are 57 to 58 years old and in "poor" condition and the maintenance-of-way buildings are 43 to 78 years old and in "poor" condition (about 2.9 million square feet).

The commuter rail system has 17 major buildings and 1 of these is in "bad" condition, 15 are in "poor" condition, and 1 is in "fair" condition. The carhouse in "bad" condition is approximately 50 years old (and contains 44,000 square feet; the carhouses in "poor" condition range in age from 11 to 84 years and contain about 1.1 million square feet. The maintenance facility building in "fair" condition is approximately 50 years old. One of the support facilities was constructed in 1957 and is generally too small, not equipped properly and should have extensive repairwork. Problems in the other buildings include poor lighting and equipment, areas too small for storage and spare parts, poor drainage at the car wash facilities, inadequate fixtures and equipment at the carshops, and some structural problems.



Electric Car Shop

- NORTHERN NEW JERSEY

The rapid rail system has 4 major maintenance facility buildings and 1 of these is in "bad" condition and the other 3 are in "fair" condition. The maintenance facility building in "bad" condition is approximately 82,000 square feet and should be replaced. One of the maintenance facility buildings in "fair" condition was constructed as an interim short term measure only; it requires some improvement. The larger maintenance facility that is presently in "bad" condition should be replaced with a new and larger building.

The light rail system has 1 major maintenance facility, which is 49 years old, in "good" condition and contains 8,000 square feet. The condition of this building varies but is acceptable. Although the carwash facilities in the yard area are manual, the cars appear clean and well washed. The office areas and some of the facilities are too small for efficient operations, but are adequate.

Small Work Area

The commuter rail system has 5 maintenance shops, including 4 shops that are in "poor" condition that are between 55 and 84 years old. The shop in "good" condition is approximately 14 years old. The shops in "poor" condition will no longer be used when the Meadowlands Maintenance Facility is placed into service in 1987.

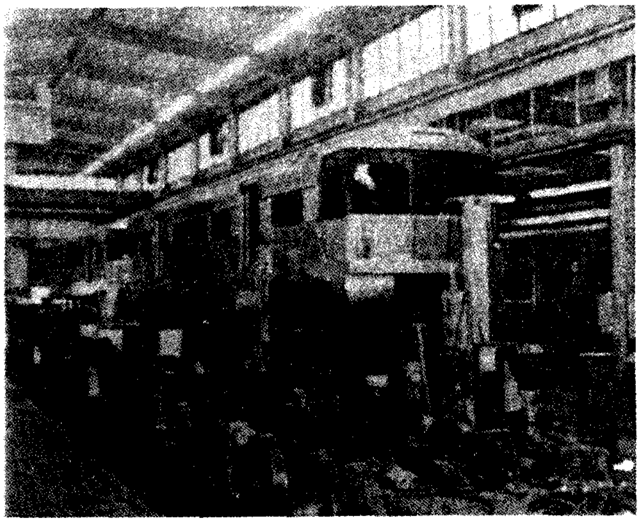
- SOUTHERN NEW JERSEY

The rapid rail system has 3 maintenance facility buildings which are all in "good" condition. These buildings contain 106,000 square feet. Although these buildings are in "good" condition, dust collecting equipment is needed in the blowout facility and temporary heating for employees in the carwash area should be considered.

- PHILADELPHIA

The rapid rail system contains 4 major maintenance buildings; 1 in "poor" condition, and 3 in "fair" condition. The carhouse building in "poor" condition is approximately 58 years old and contains 40,000 square feet. The 3 carhouse/carshop buildings in "fair" condition range in age from 58 to 77 years. The shop in "poor" condition requires extensive renovations to update the facility. Modernization is necessary to provide inspection and repair of the new cars and to centralize rail vehicle major components and rebuild operations for the Broad Street subway fleet.

The light rail system has 4 carhouse buildings, which range from "bad" to "good" condition. The carhouse in "bad" condition is approximately 77 years old, and contains 28,000 square feet. the carhouse in "poor" condition is 72 years old and the carhouse building in "fair" condition is approximately 71 years old. The carhouse in "good" condition is only 3 years old and contains



Car House Building

45,000 square feet. Some of the problems with the older buildings include roof leaks and cracked concrete floors in several places, exposed wall reinforcement and shop equipment which is approximately 60 years old and obsolete. One carshop is undersized for the functions required and the movement of cars is inefficient due to the stub-ended tracks.

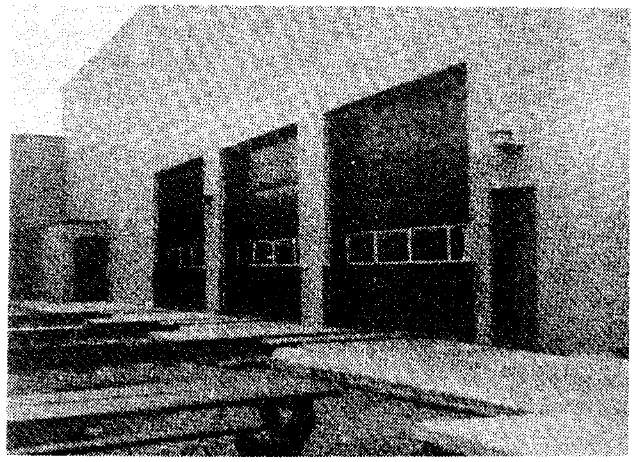
The commuter rail system has 2 major maintenance facility buildings; 1 carshop in "bad" condition that is 69 years old and contains 33,000 square feet. The carshop in "fair" condition is 49 years old. The carshop in "bad" condition has deteriorating exterior walls and the wood roof is leaking. Current drainage systems are "poor" at both shops and the heating/ventilation is inadequate.

- PITTSBURGH

The light rail system has a new maintenance facility and the building is in "excellent" condition.

- WASHINGTON, DC

The rapid rail system contains 3 major maintenance facility buildings; 1 is in "fair" condition and 2 are in "good" condition. The carshop in "fair" condition is approximately 10 years old and was not properly equipped when it was built; it contains about 186,000 square feet. Some additional equipment is needed to provide it with a full maintenance capability. The other 2 carhouses range in age from 2 to 5 years and are only in "good" condition because they also require additional equipment and



Car House

capability to bring them to an "excellent" condition.

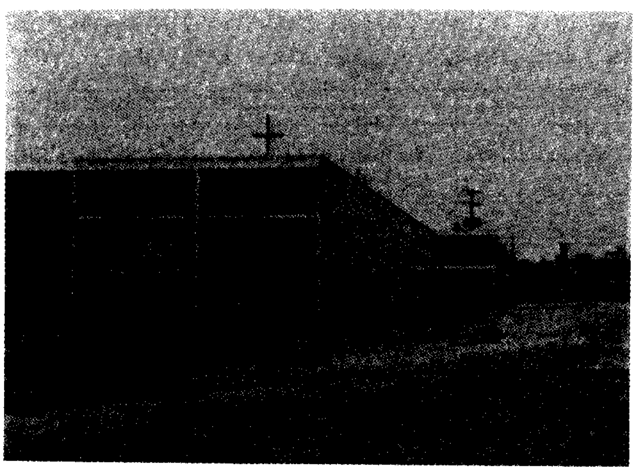
- CHICAGO

The rapid rail system has 11 major maintenance facility buildings, including repair/inspection shops that range in age from 1 to 89 years. The shop that is 1 year old is in "good" condition; 3 shops are from 77 to 89 years of age and are in "poor" condition. Seven shops range in age from 9 to 57 years, contain 287,000 square feet and are in "fair" condition. Some of the noted deficiencies include repair shop roofs, skylights, exterior doors, ovens in the motor repair area, existing transfer tables, degreasing equipment, inspection pits, ventilation and emergency lighting, exterior lighting, and stinger systems at the new pit area, and carwash operations which are exposed to the elements with no recycling of the rinse water during washing operations.

The commuter rail system has 10 major maintenance facility buildings; 7 of these are in "poor" condition and contain 279,000 square feet. One is in "fair" condition and 2 in "good" condition. The buildings in "poor" condition range in age from 35 to 80 years. The building in "fair" condition is approximately 67 years old and contains 35,000 square feet. The 2 buildings in "good" condition are 14 and 67 years old and contain 518,000 square feet.

- CLEVELAND

The rapid rail and light rail maintenance facility buildings include 9 major buildings that range from "fair" to "excellent" condition. The 3 buildings in "excellent" condition have just been completed, are approximately 2 years old and contain 242,000 square feet. The transportation building is about 15 years old and is in "good" condition. The other carhouse and shops and the transportation building range in age from 10 to 30 years and are in "fair" condition (about 40,000 square feet).



Inspection Shop

- ATLANTA

The rapid rail system has 2 major maintenance facility buildings, including a shop that is 7 years old and a maintenance-of-way building that is approximately 7 years old. Both of these buildings are in "good" condition.

- NEW ORLEANS

The light rail system has 2 major maintenance facility buildings; 1 carshop that is 149 years old and a maintenance-of-way building that is 79 years old. These buildings are both in "fair" condition and contain 103,000 square feet. Problems include roof and wall leaks and cracks in the walls that should be repaired. Some of the equipment is old and unreliable and should be replaced. The work space is inadequate and machines are located too close to each other. Ventilation in the work areas is often poor and excessive dust is in the air. The electrical and drainage problems also exist and some cracking in the wall was observed and should be repaired.

- SAN FRANCISCO

The rapid rail system contains 14 major buildings and all range from "good" to "excellent" condition. The administration building in one of the blowdown buildings has just been completed and is in "excellent" condition. The other 12 buildings are about 14 years and are in "good" condition.

The light rail maintenance facility includes 2 major buildings, 1 which was completed 7 years ago and is in "good" condition, the other building is approximately 89 years old, but has recently been rehabilitated and is also in "good" condition.

- SAN DIEGO

The light rail system has 1 maintenance facility building, which is only 3 years old and in "excellent" condition.

o Maintenance/Storage Yard Condition

The condition of the maintenance/storage yards for the rail transit systems is provided in Table 3.16. The rapid rail systems have 59 yards; 32 in "poor" condition (25 of these are in New York), 15 in "fair" condition (8 in Chicago and 4 in Boston), 11 in "good" condition and 1 in "excellent" condition. The light rail systems have 12 yards; 2 in "bad" condition (Philadelphia), 3 in "fair" condition (Boston), and the remainder are in "good" or "excellent" condition. The commuter rail systems have 61 yards; 4 in "bad" condition, 29 in "fair" condition (all in Northern New Jersey and Chicago) and the remaining 4 are in "good" or "excellent" condition.

A discussion follows of the maintenance/storage yard condition for each of the major rail areas, with some emphasis on items of particular concern:

- BOSTON

The rapid rail system has 4 yards which range in age from 9 to 34 years and all are in "fair" condition (about 2 million square feet).

The light rail system has 5 maintenance/storage yards. Three are in "fair" condition and they range in age from 9 to 55 years. One yard in "good" condition is approximately 5 years old and contains 96,000 square feet. One of the yards is in "excellent" condition since being reconstructed.

The commuter rail system has 1 maintenance/storage yard, which is in "bad" condition and is almost 84 years old (approximately 218,000 square feet).

TABLE 3.16

MAINTENANCE/STORAGE YARD CONDITION (Thousands of Square Feet)

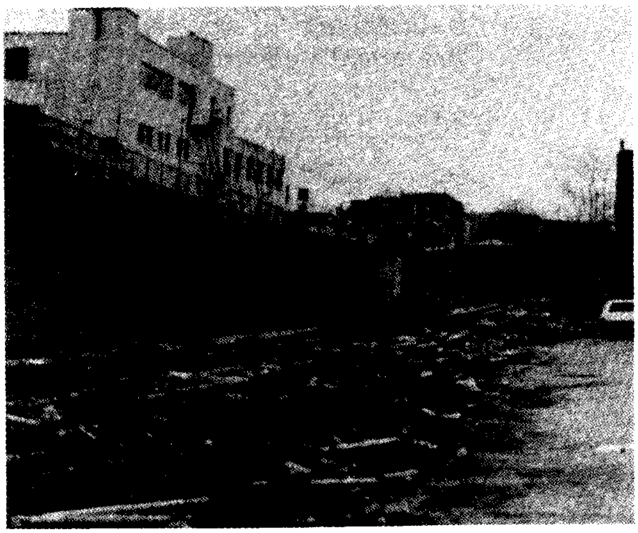
Major Rail Areas	Rapid Rail						Light Rail						Commuter Rail					
	E	G	F	P	B	T	E	G	F	P	B	T	E	G	F	P	B	T
Boston	-	-	2039	-	-	2039	83	96	632	-	-	811	-	-	-	-	218	218
New York	-	-	-	20125	-	20125						NA	320	-	-	5377	-	5697
Northern NJ	-	-	-	653	-	653	-	64	-	-	-	64	-	-	3163	-	-	3163
Southern NJ	-	871	-	-	-	871						NA						NA
Philadelphia	-	-	-	1238	-	1238	-	318	-	-	237	555	-	-	-	1045	741	1786
Pittsburgh						NA	52	-	-	-	-	52						NA
Washington, DC	-	1168	-	-	-	1168						NA						NA
Chicago	-	671	2208	793	-	3672						NA	-	1289	8187	4116	1025	14617
Cleveland	-	554	-	188	-	742	-	-	-	-	-	None						NA
Atlanta	500	-	-	-	-	500						NA						NA
New Orleans						NA	-	-	-	-	-	None						NA
San Francisco	-	3920	-	-	-	3920	-	348	-	-	-	348						None
San Diego						NA	-	684	-	-	-	684						NA
TOTAL	500	7184	4247	22997	-	34928	135	1510	632	-	237	2514	320	1289	11350	10538	1984	25481

Legend: E - Excellent G - Good F - Fair P - Poor B - Bad T - Subtotal

NA - Not Applicable

- NEW YORK

The rapid rail system has 25 maintenance/storage yards, all of which are presently in "poor" condition and contain about 20 million square feet. These yards range in age from 36 to 80 years; five are presently funded for modernization.



Storage Yard

The commuter rail system has 13 yards, 12 are in "poor" condition, and 1 is in "excellent" condition. The yard in "excellent" condition is brand new. The other yards are in "poor" condition and all are about 84 years old.

- NORTHERN NEW JERSEY

The rapid rail system has 3 maintenance/storage yards and they are all in "fair" condition. These yards contain approximately 653,000 square feet of area. The yards have serious rail wear as well as numerous failures with the automatic switching.

The light rail system has 1 yard, which is 49 years old, in "good" condition and contains 64,000 square feet.

The commuter rail system has 14 yards and these are all in "fair" condition. These yards are all about 84 years old.

- SOUTHERN NEW JERSEY

The rapid rail system has 1 maintenance/storage yard which is in "good" condition. This yard contains approximately 871,000 square feet and will require improvement during the next 10 years. The drainage is very "good" on this yard and the track is in "good" condition.

- PHILADELPHIA

The rapid rail system has 3 yards all in "poor" condition. These yards range in age from 58 to 77 years and contain about 1.2 million square feet.

The light rail system has 3 yards, 2 in "bad" condition and 1 in "good" condition. The 2 yards in "bad" condition are from 72 to 77 years old and the yard in "good" condition is only 3 years old and contains 318,000 square feet.

The commuter rail system has 3 yards; 2 in "bad" condition and 1 in "poor" condition. The 2 yards in "bad" condition are both 69 years old (about 741,000 square feet) and the yard in "fair" condition is about 49 years old (about 1 million square feet).

- PITTSBURGH

The light rail system has a recently completed yard, which is in "excellent" condition.

- WASHINGTON, DC

The rapid rail system has 3 maintenance/storage yards, all of which are in "good" condition and range in age from 2 to 10 years.

- CHICAGO

The rapid rail system has 12 yards, 2 in "poor" condition, 8 in "fair" condition and 2 in "good" condition. The two yards in "poor" condition are 57 and 72 years old and contain about 793,000 square feet. The 8 yards in "fair" condition range in age from 9 to 89 years. The 2 yards in "good" condition are 1 and 22 years old and contain 671,000 square feet.

Yard and Car Wash

The commuter rail system has 30 yards, 1 in "bad" condition, 11 in "poor" condition, and 15 in "fair" condition. The yard in "bad" condition is approximately 74 years old and contains more than 1 million square feet. The 11 yards in "poor" condition range in age from 35 to 74 years and contain more than 4.1 million square feet. The yards in "fair" condition range in age from 8 to 130 years. The 3 yards in "good" condition are from 2 to 5 years old and contain almost 1.3 million square feet.

- CLEVELAND

The rapid rail and light rail systems have 4 yards; 2 in "poor" condition and 2 in "good" condition. The 2 yards in "poor" condition range in age from 15 to 30 years and contain about 188,000 square feet. The 2 in "good" condition range from 2 to 15 years of age and contain 554,000 square feet.

- ATLANTA

The rapid rail system has 1 new maintenance yard, which is in "excellent" condition.

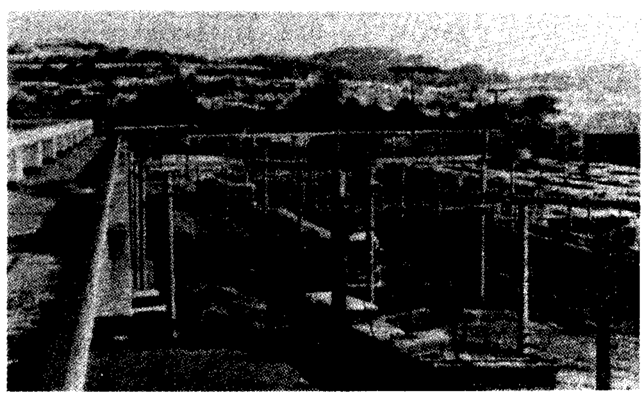
- SAN FRANCISCO

The rapid rail system has 3 yards; all of which are in "good" condition and are approximately 7 years old.

The light rail system has 1 maintenance yard and it is in "good" condition.

- SAN DIEGO

The light rail system has 1 maintenance/storage yard, which is 3 years old and in "good" condition.



Maintenance/Storage Yard

3.4 SYSTEM ELEMENT DETERIORATION

One of the key objectives of the Rail Modernization Study was to obtain some understanding of the rate of deterioration of the various system elements and major subsystems. The results of this evaluation are provided in the next two sections of this report. The first method provides some insight into the reduction in remaining life of each system element or major subsystem as the age increases. The second method provides some insight into the change in condition versus age for different types of preventive maintenance programs.

3.4.1 AGE VERSUS REMAINING LIFE

The Rail Modernization Study has adapted a recognized method of determining the deterioration of capital investments that was originally developed in 1935 at Iowa State University. The so called "Iowa Type Survivor Curves" were employed to estimate the remaining life and deterioration rate of the applicable system elements. As stated in the abstract of Bulletin 125: "In making engineering valuations and in determining depreciation expense, the probable service lives of the units of property under consideration are very significant. Though in practice, probable service lives are determined by various methods, the most reliable are those statistical methods which take into consideration retirement experience with similar property."

The statistical analysis method used to actually calculate remaining life versus age was essentially the same as used for other types of industrial property retirements. An original expected life of each applicable system element was estimated, an appropriate survivor curve was selected that best represented the survival rate of each system element, and then the present age and estimated condition (i.e., excellent, good, etc.) were used to obtain a statistical estimate (revision) of the remaining life in years. The survivor curves were obtained from previously calculated Iowa Survivor Curve tables and evaluated to determine their applicability. The general procedures for obtaining each estimate of remaining life were as follows:

- Estimate the remaining life before adjusting for "present condition" by using the survivor curves and the following formulas.
  - AP = PA/OEL
  - PLP is obtained from the "survivor tables"
  - PL = PLP x OEL
  - RL = PL - OEL

  where:
  AP = Age Percent
  PA = Present Age
  OEL = Original Expected Life
  PLP = Probable Life Percent
  PL = Probable Life
  RL = Remaining Life

- Adjust the estimate of the remaining life for the "present condition" by determining:
  - The expected age range (EAR) of percentages for the observed conditions.
  - The associated age range (AER) which is equal to: EAR (percentage) x PL (NOTE: This associated age range provides both a "high" and "low" estimate.)
  - If the "low" estimate is less than the actual age and the "high" estimate is greater than the actual age (i.e., actual age is between the two estimates), then the remaining life is the same as previously calculated (before the adjustment).
  - If the "low" estimate is greater than the actual age or the "high" estimate is lower than the actual age, then the following procedure was used to estimate the adjusted remaining life:
  - AP (adjusted) = AER (low)/OEL PLP (adjusted) was obtained by entering the "survivor tables" with AP (adjusted)

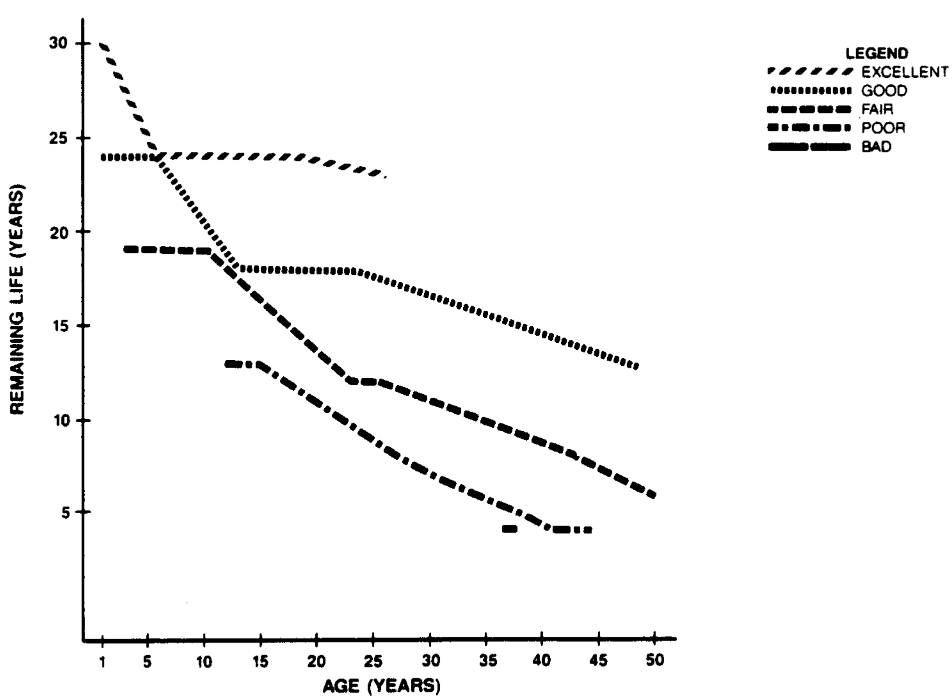
PL = PLP (adjusted) x OEL
RL (adjusted) = PL (adjusted) - AER (low)

In view of the relatively large amount of data obtained on the current condition of each system element, the necessity to use different types of survivor curves, and the selection of different "original expected lifes" for each system element, a computer program was developed. This program provides plots of age versus remaining life for <u>each</u> present condition (i.e., excellent, good, etc.). The following curves illustrate the type of deterioration that was estimated by the preceding statistical analysis method as a result of the observations obtained from the inspections of the nation's transit systems.

- Track. The remaining life versus age curves for track are illustrated in Figure 3.1. It can be observed that some of the track remains in "excellent" condition out to approximately 26 years and in a "good" condition out to slightly less than 50 years. It could be assumed that if the deterioration followed the normal survivor curve, the minimum condition would be achieved in a period of between 40 and 45 years, as illustrated by the "poor" curve. Deviation from this normal survivor curve is of particular interest and it can be concluded that major changes in this depreciation occurred at 7 years, 13 years, and 23 years. At 7 years, some of the track remained in "excellent" condition while some of the track deteriorated to a "good" condition. Since approximately 63 percent of the track that was inspected was receiving some type of normal preventive maintenance, it can be concluded that some additional capital expenditures would probably be required to maintain this "excellent" condition out to a period of approximately 26 years. In conclusion, it can be assumed that some additional major maintenance occurred at 13 years where some of the track remained in "excellent" condition out to slightly less than 50 years. Again, at 23 years it can be concluded that some of the "fair" track received some type of major rehabilitation in order to decrease the rate of deterioration to a "poor" condition. Of particular concern is that some of the track deteriorated at a rate faster than the normal deterioration, as indicated by the fact that some of the track had deteriorated to a "fair" condition in less than 3 years and to a "poor" condition in less than 12 years.

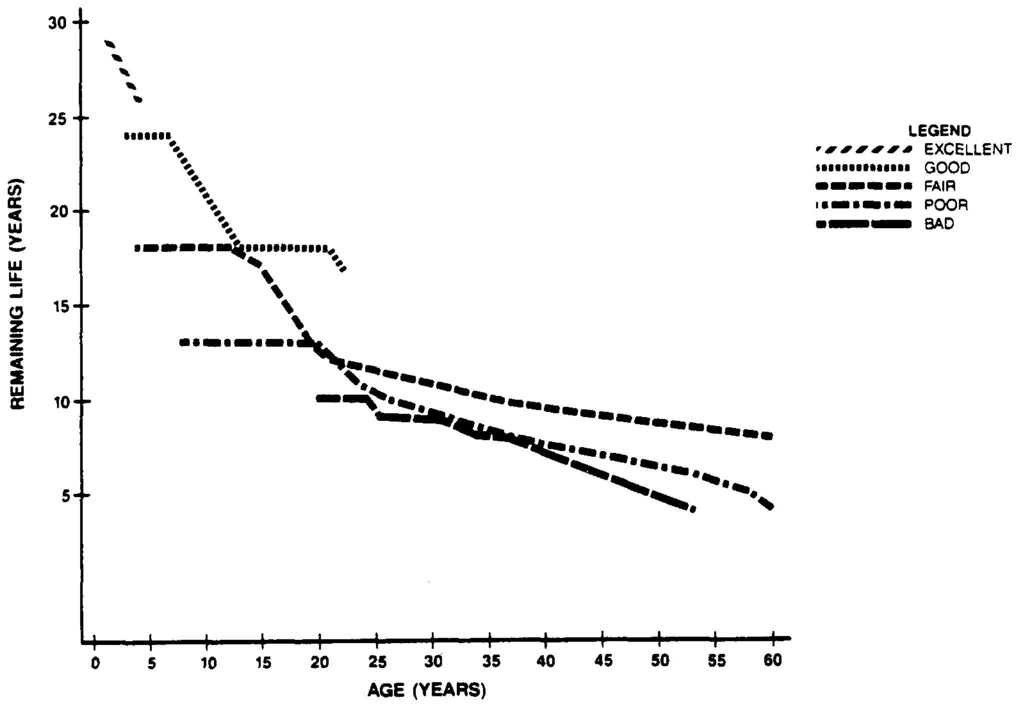
FIGURE 3.1

TRACK



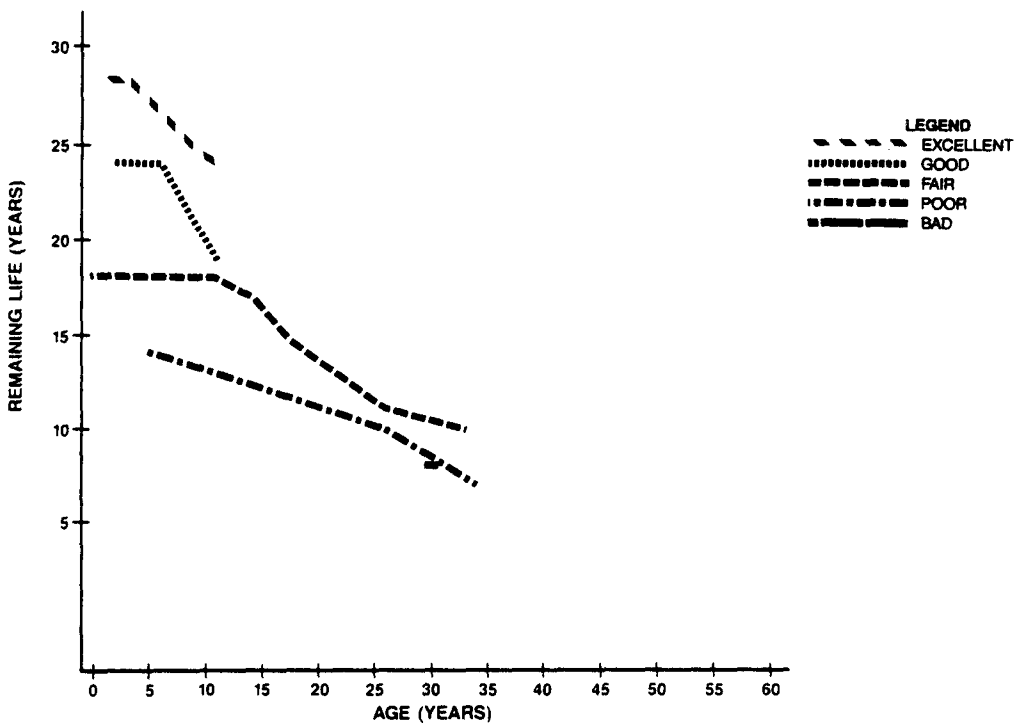
- Vehicles - Self-Propelled Rail Cars. The remaining life versus age curves for self-propelled rail cars are illustrated in Figure 3.2. It can be observed that some rail cars remained in excellent condition out to 20 years of operation and some were still in "fair" condition after almost 60 years. It can be assumed that under normal deterioration, the rail cars should have deteriorated to a minimum condition in approximately 30 to 35 years. Of particular interest is the fact that some of these rail cars deteriorated at lower rates than indicated by the normal survivor curve and also that some of them deteriorated at a much faster rate. For example, after 12 years of operation, some of the cars remained in "excellent" condition for another 10 years while others deteriorated to a "fair" condition. Since approximately 61 percent of these self-propelled rail cars were being maintained by some type of normal preventive maintenance program, it can be assumed that some additional modernization or rehabilitation was required at about 12 years to maintain this "excellent" condition. Also of interest is the fact that some of these rail cars deteriorated to a "fair" condition after less then 5 years of operation and some had already deteriorated to a "poor" condition after slightly less than 8 years of operation. Since it is assumed that a normal maintenance program should assist in slowing the deterioration indicated by the normal survivor curve, it can be concluded that the earlier deterioration may be due to the lack of a formal preventive maintenance program and the type of equipment.

FIGURE 3.2
VEHICLES
SELF-PROPELLED RAIL CARS



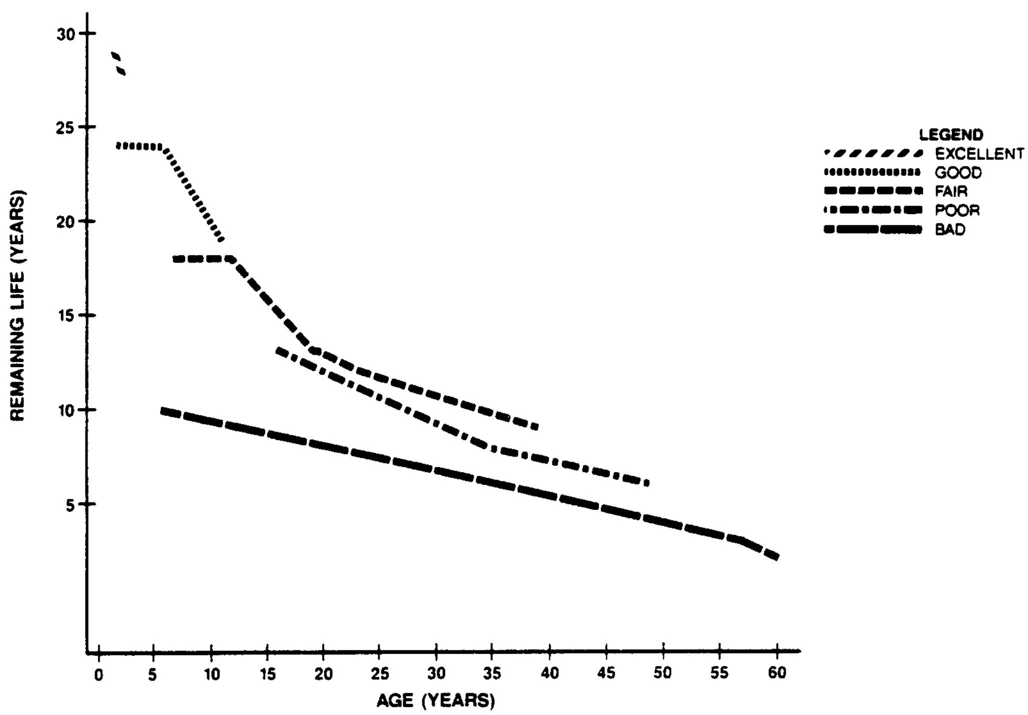
- Vehicles - Locomotives. The remaining life versus age curves for locomotives are illustrated in Figure 3.3. These curves indicate that some locomotives have remained in "excellent" condition out to approximately 12 years and some have remained in "fair" condition out to more then 30 years of operation. It can be assumed, from this information, that the maximum depreciation would occur in a period of 30 to 35 years using the standard survivor curve. Although there was not much data to indicate that the normal deterioration could be stopped, there are some major concerns in that some of the locomotives had deteriorated to a "fair" condition very early and some had deteriorated to a "poor" condition in less than 5 years of operation. Since approximately 71 percent of the locomotives were being maintained by some type of normal preventive maintenance program, it can be assumed that the early deterioration was a result of insufficient preventive maintenance.

FIGURE 3.3
VEHICLES
LOCOMOTIVES



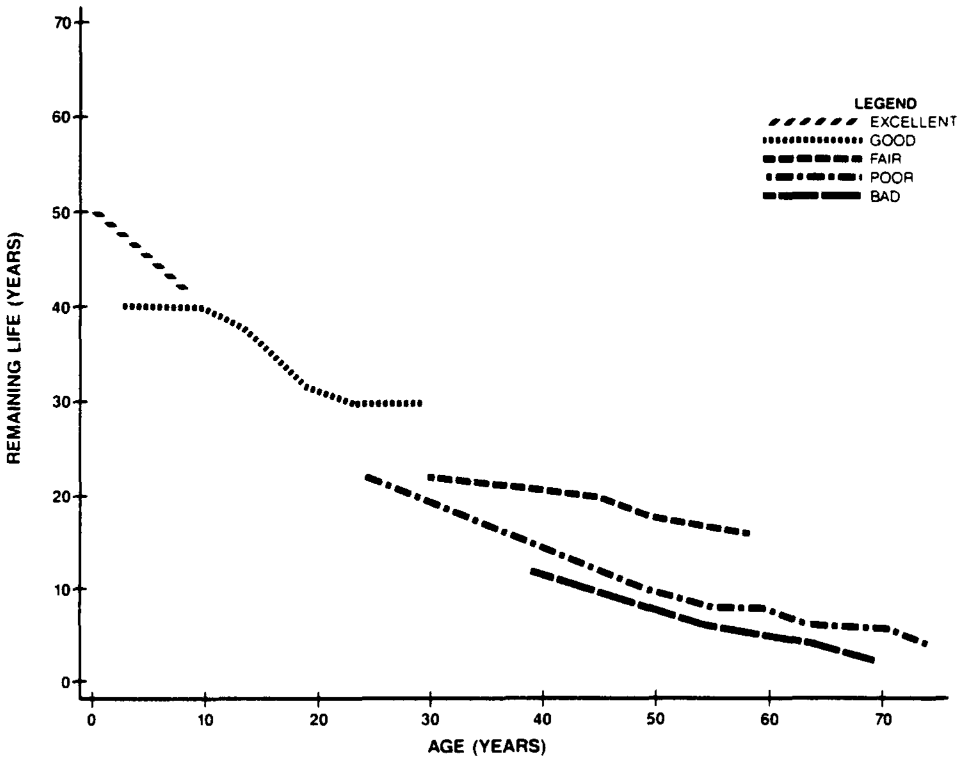
- Vehicles - Unpowered Cars. The remaining life versus age curves for unpowered cars are illustrated in Figure 3.4. This data indicates that some unpowered cars remained in "excellent" condition out to a period of approximately 11 years and then deteriorated to either a "fair" or "poor" condition shortly thereafter. It can be assumed that maximum deterioration should occur in a period of 30 to 35 years if only normal preventive maintenance were performed on these unpowered cars, especially since 82 percent of these cars were being maintained by some type of formal program. Of particular concern is the fact that some unpowered cars deteriorated faster than normal, as indicated by the fact that some of these cars had deteriorated to a "fair" condition in less than 8 years and some cars had even deteriorated to a "poor" condition in approximately 5 years.

FIGURE 3.4
VEHICLES
UNPOWERED CARS



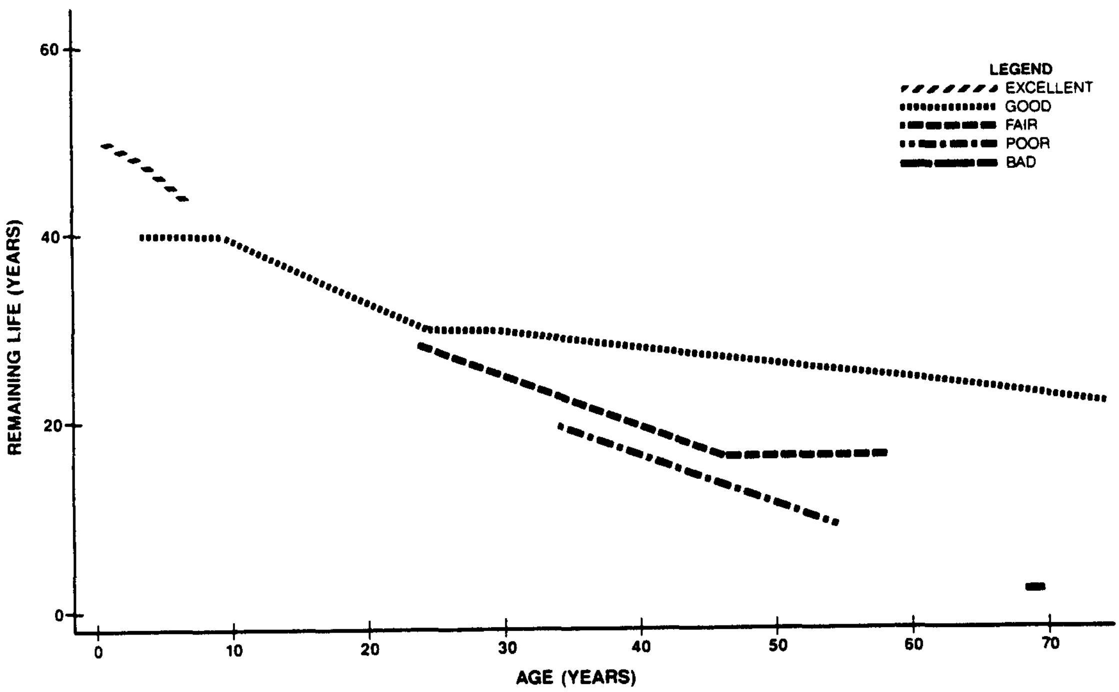
- Power Distribution - Substations. The remaining life versus age curves for the substations are illustrated in Figure 3.5. The data indicates that some power distribution substations remained in "excellent" condition out to approximately 29 years and that some remained in "good" condition out to slightly more than 29 years. It can be assumed that maximum deterioration should occur in 40 to 50 years under the assumptions of the normal survivor curve for this system element. Of special interest is the fact that some power distribution substations remained in better condition than indicated by the normal survivor curves. For example, at somewhat less than 19 years, some power distribution substations remained in excellent condition for another 10 years. In addition, some power distribution substations remained in "fair" condition, after having been in operation for 30 years, for another 30 years. Since 91 percent of the power distribution substations were maintained by some type of normal preventive maintenance program, it can be assumed that some type of additional rehabilitation or modernization program was instituted to maintain the condition above the normal rate of deterioration.

FIGURE 3.5
POWER DISTRIBUTION SUBSTATION



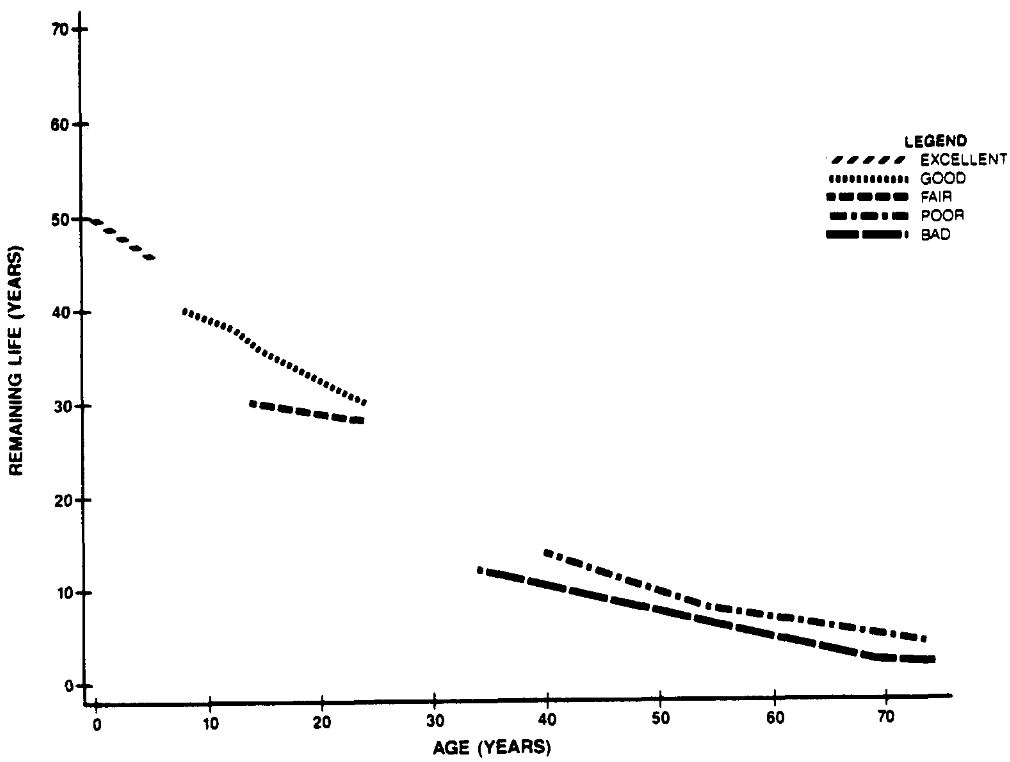
- Power Distribution - Overhead Wire. The remaining life versus age curves for the power distribution overhead wire are indicated in Figure 3.6. This data indicates that some power distribution overhead wire remained in "excellent" condition out to approximately 50 years and some wire was in "good" condition out to more than 70 years of service. However, this information seems to imply that maximum deterioration should occur during 50 to 60 years of operation under conditions of normal depreciation. Since 100 percent of the power distribution overhead wire is maintained by some type of formal normal preventive maintenance program, it can be concluded that these programs assist in reducing the rate of deterioration, as indicated in Figure 3.6.

FIGURE 3.6
POWER DISTRIBUTION OVERHEAD WIRE



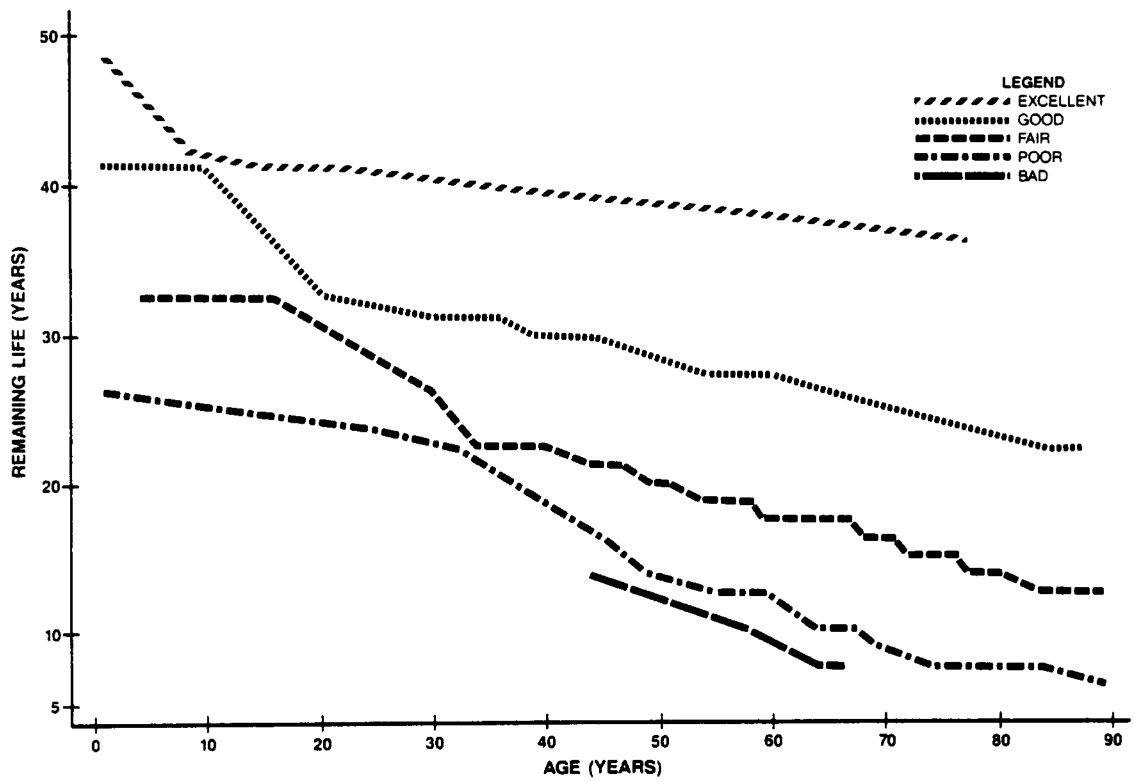
- Power Distribution - Third Rail. The remaining life versus age curves for the power distribution third rail are illustrated in Figure 3.7. This data indicates that some third rail remained in "excellent" condition out to approximately 5 years and that some rail has remained in "good" condition out to about 25 years. The curves also indicate that the deterioration has nearly achieved the maximum value in 50 to 60 years (i.e., curves begin to flatten out). Since 96 percent of the power distribution third rail is maintained by some type of formal normal maintenance, it can be concluded that these programs are sufficient to maintain a relatively consistent deterioration. However, some deterioration has been greater than the normal deterioration, as indicated by the fact that some third rail has deteriorated to a "fair" condition in approximately 12 years and other rail has depreciated to a "bad" condition in approximately 34 years.

FIGURE 3.7
POWER DISTRIBUTION THIRD RAIL



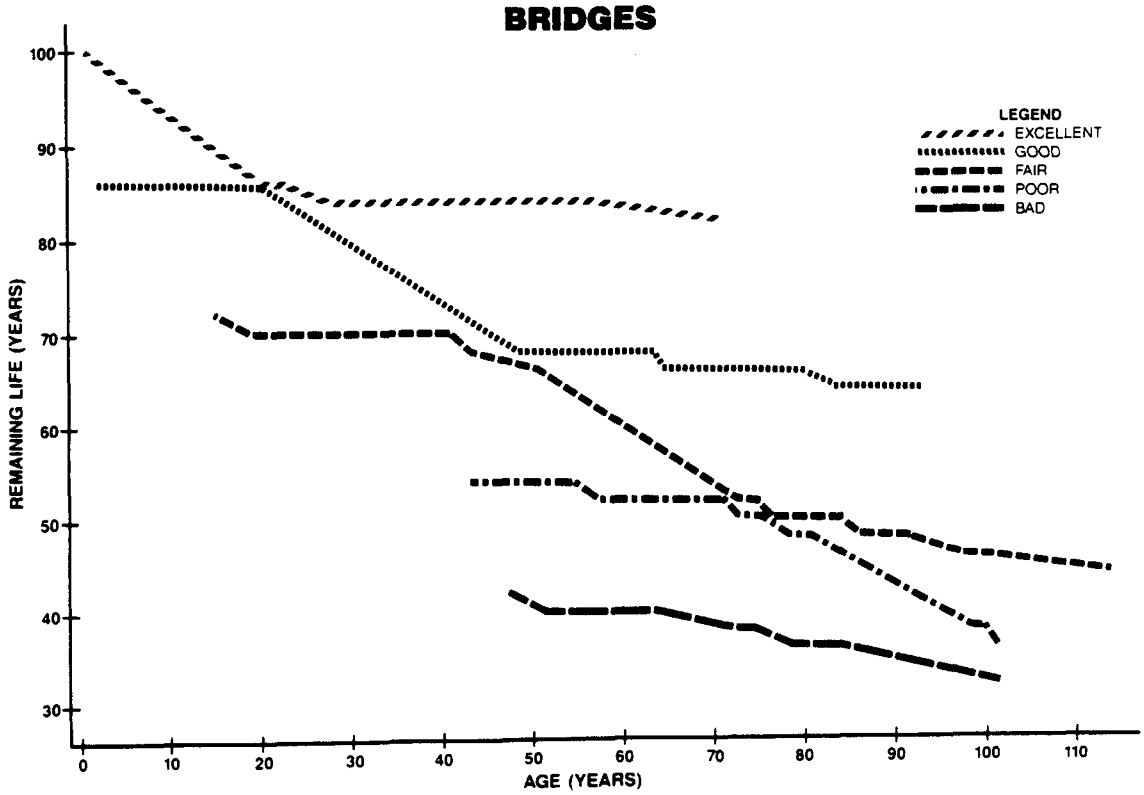
- Stations. The remaining life versus age curves for the stations are illustrated in Figure 3.8. It can be observed that some stations have remained in "excellent" condition for almost 80 years and some stations have remained in "good" condition for almost 90 years. It can also be assumed that deterioration has nearly achieved the maximum value between the 60th and 70th year, as indicated by the "poor" and "bad" conditions. As a result, it is of special interest to determine why some stations have deviated so significantly, both above and below the normal deterioration curve. For example, after 10 years of operation, some stations have remained in "excellent" condition for a relatively long period of time as shown in the figure; it could be assumed that some additional maintenance or rehabilitation was performed on these stations at about the 10th year of service. The same conclusion can be made for the 20th year, when some stations did not deteriorate at the normal rate and remained in "good" condition for almost 90 years. Of particular concern is the fact that some stations deteriorated much more rapidly then indicated by the normal survivor curve. For example, some stations were only in a "fair" condition after less then a few years of operation and some stations have deteriorated to a "fair" condition after approximately 5 years of service. Since only 40 percent of the stations were being maintained by some type of maintenance program, it can be assumed that the lack of such a program may have contributed to this rapid deterioration.

FIGURE 3.8
STATIONS



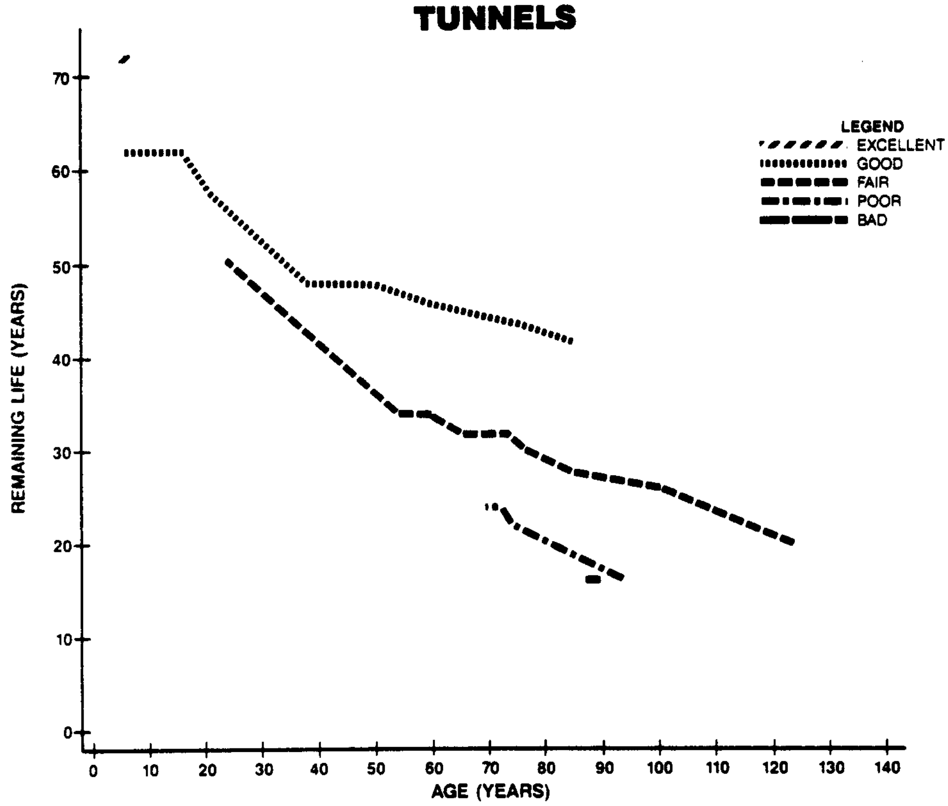
- Structures and Facilities - Bridges. The remaining life versus age curves for the bridges are illustrated in Figure 3.9. It can be observed from this data that some bridges have remained in "excellent" condition out to approximately 70 years and some are even in "good" condition after more than 90 years of operation. It can be assumed that maximum deterioration of these bridges should not occur until nearly the 100th year of service. However, some bridges have deteriorated at a sigificantly lower rate then others, which have depreciated much faster then indicated by the normal survivor curve. For example, after 20 years of service, some bridges have remained in "excellent" condition for another 50 years; also, after 41 to 48 years of service, other bridges have remained in a "good" condition for almost another 40 years. Since only 23 percent of the bridges were being maintained by some type of normal preventive maintenance program, it can be assumed that the bridges which were covered by such a program probably deteriorated at a much lower rate then the average and that some type of additional capital expenditures have been performed on these bridges between the 20th and 50th year of service. It can also be observed that some bridges have deteriorated at a much faster rate then normal, as indicated by the fact that some bridges were only in a "fair" condition after slightly 16 years of operation and some bridges had already deteriorated to a "poor" condition after slightly less then 42 years of service. Some bridges had deteriorated to a "bad" condition after 50 years of service and this is of special interest because of the fact that major corrective action is required on these bridges at intervals of less then 6 months; this increases both operating costs and requirements for future major capital improvements.

FIGURE 3.9
STRUCTURES AND FACILITIES
BRIDGES



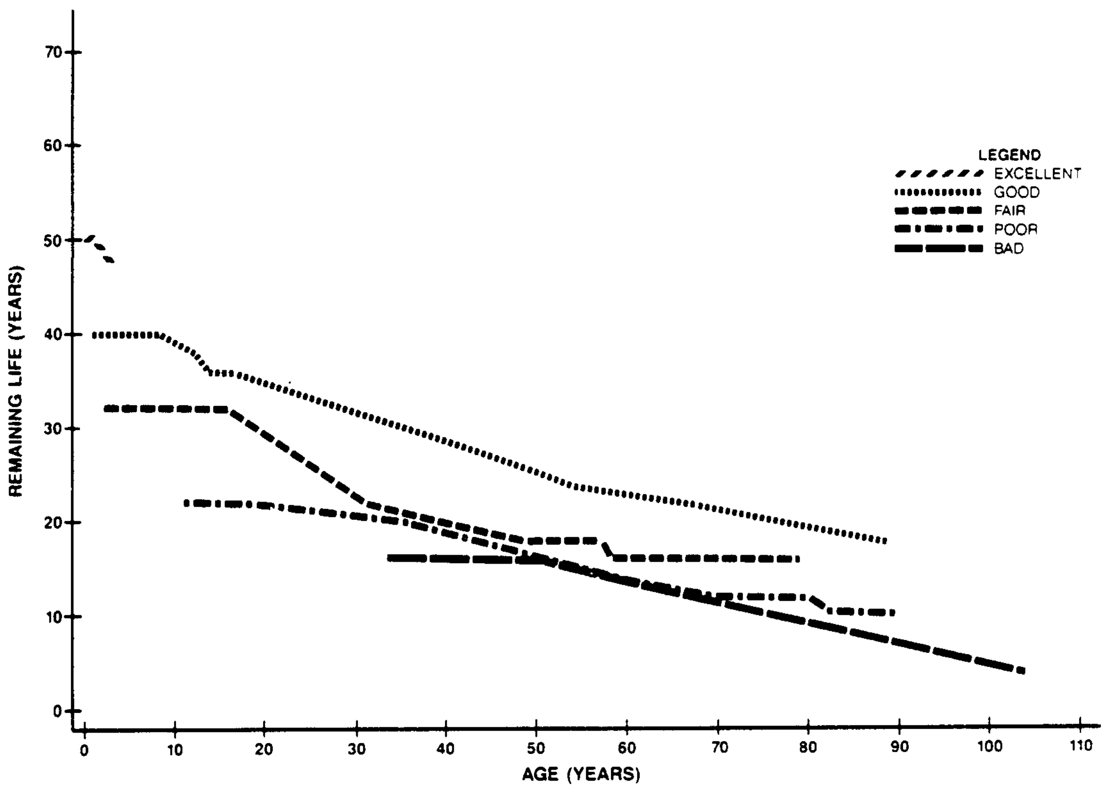
- Structures and Facilities - Tunnels. The remaining life versus age curve for tunnels are illustrated in Figure 3.10. This data indicates that some tunnels have remained in "good" condition for more then 80 years but that some have deteriorated at a relatively rapid rate. This data indicates that maximum deterioration should probably be expected to occur at some time between the 80th and 100th year of service. However, after 40 years of service, some tunnels have remained in "good" condition for another 40 years; this implies that some type of major refurbishment or rehabilitation program was instituted to halt the normal deterioration. Also at approximately the 55th year of service, some tunnels were maintained in a "fair" condition for another 60 to 70 years, which is also significantly different than the expected deterioration. Since only 33 percent of the tunnels were maintained by some type of formal normal preventive maintenance program, some of this reduction in deterioration may be due to those programs.

FIGURE 3.10
STRUCTURES AND FACILITIES
TUNNELS



- Maintenance Facility Buildings. The remaining life versus age curves for maintenance facility buildings are illustrated in Figure 3.11. This data indicates that some buildings have remained in "good" condition out to almost 90 years of service. It can also be assumed that the maximum deterioration should occur at some time between the 50th and 60th year of service. Therefore, it can be concluded that some type of additional capital or operating expenditures are required to maintain these buildings and to reduce the rate of deterioration. For example, after approximately 15 years of service, some buildings deteriorated at much lower rates than indicated by the normal survivor curve and remained in "good" condition for a relatively long period of time (out to approximately 90 years). Since only 22 percent of the maintenance buildings were maintained by some type of normal maintenance program, it can be assumed that the change in deterioration was probably caused by the institution of some type of more formal normal maintenance program or additional capital expenditure and possibly both.

FIGURE 3.11
MAINTENANCE FACILITY BUILDINGS



3.4.2 CONDITION VERSUS AGE FOR DIFFERENT MAINTENANCE PROGRAMS

During the conduct of this study, four different kinds of maintenance programs were evaluated to determine their possible influence on deterioration of the major system elements. It is not being suggested that any of these is the ideal, of course. But they do represent four headings under which most of the actual maintenance practices that were encountered can be clustered. These four programs were generally defined as follows:

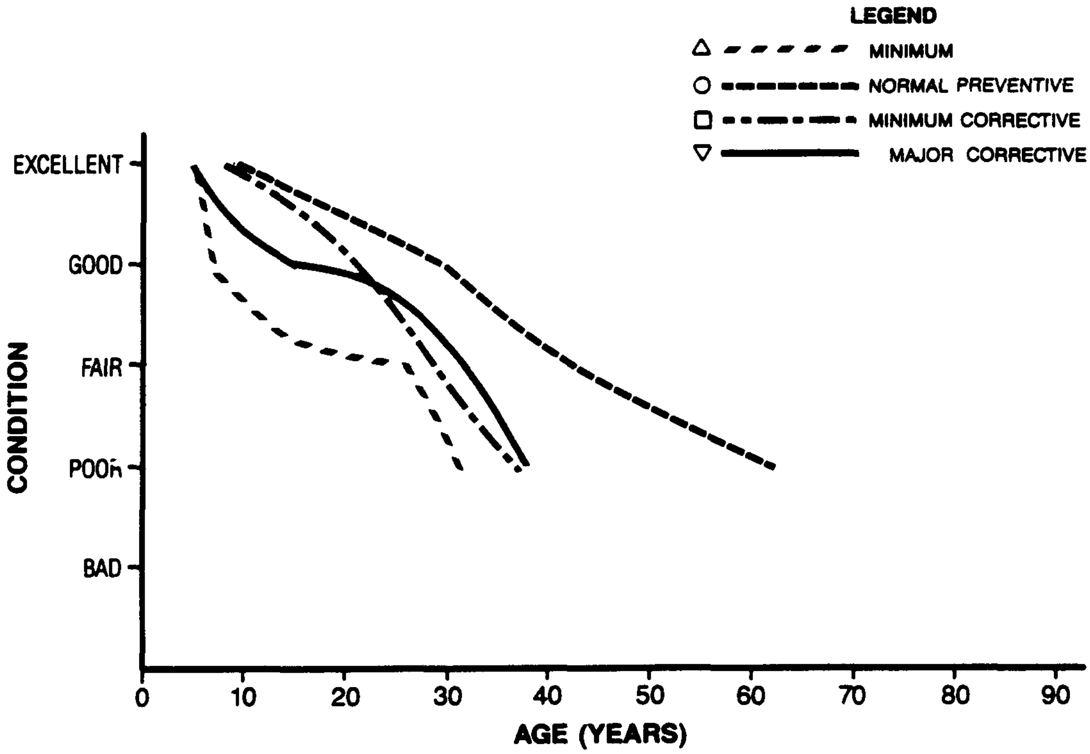
- Minimum: A program primarily designed to maintain the physical appearance of track, vehicles, power, stations, structures, etc. Although mostly oriented toward aesthetics, including cleanliness and general appearance, deterioration should be reduced by the early reduction of rust, leaching, spalling, cracks, leaks, corrosion, rotting, and other types of deterioration caused by the interaction between the system element and the physical environment.
- Normal Preventive Maintenance: A program primarily designed to use a specific schedule of daily, weekly, monthly, and annual inspections and corrective actions for each identified deficiency.
- Minimum Corrective Action: A program primarily designed to correct immediately minor discrepancies as they occur and are detected. The major philosophical difference between this program and the two preceding programs is that only minor maintenance is performed until something happens that requires corrective action.
- Major Corrective Action: A program primarily designed to correct only major discrepancies as they occur and are detected. This type of program provides only minimal routine maintenance, even when minor discrepancies are detected, unless the discrepancy will immediately effect safety, operational reliability/availability, operating efficiency, security, or patron usage. This type of maintenance program would schedule the other types of observed minor discrepancies to be corrected at some future date, possibly in accordance with a long range general maintenance plan, but would not correct them as they occur.

The observed depreciation of each of the major system elements is discussed in the paragraphs on the following pages.

- Track. The observed average or median deterioration of the track segments inspected is illustrated in Figure 3.12 and indicates that the track condition deteriorated to a "poor" condition in 30 to 65 years, depending upon the type of preventive maintenance program being utilized. Approximately 63 percent of the track segments inspected were considered to be included in a normal maintenance program, eight percent in a minimum maintenance program, nine percent in a minimum corrective action program and about 20 percent in a major corrective action program. As indicated in this diagram, a normal preventive maintenance program appears to have significant effect on preventing deterioration of the track system element; the track was maintained in a good condition at least eight years longer than for any other type of maintenance program and 23 years longer than for a minimum program. In addition, with a normal preventive maintenance program, some of the track sections inspected remained in an "excellent" condition out to 25 years, a "good" condition out to 62 years and in a "fair" condition out to nearly 80 years.

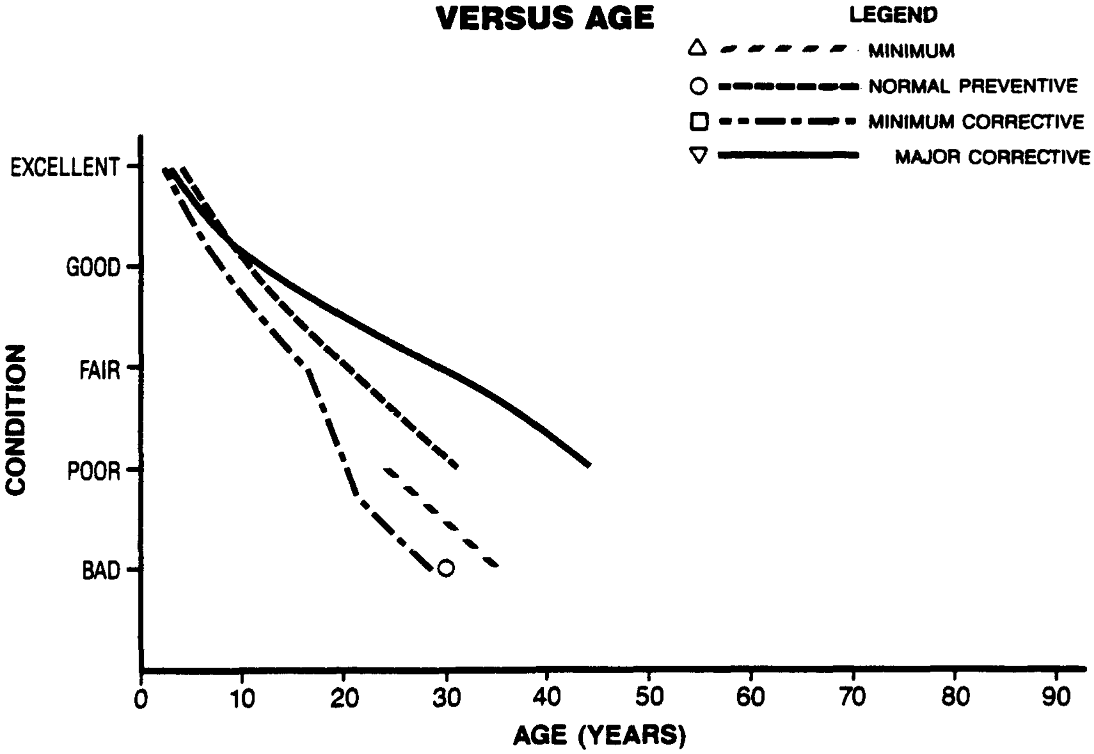
- Vehicles. Vehicle deterioration was evaluated by major type of vehicle since it was assumed that there could be major differences between self-propelled rail cars, locomotives, and unpowered cars.

FIGURE 3.12
TRACK CONDITION VERSUS AGE



Self-Propelled Rail Cars. The observed average or median deterioration of the self-propelled rail cars is illustrated in Figure 3.13. This data indicates that rail cars deteriorated to a "poor" condition in 20 to 45 years, depending upon the type of maintenance program being utilized. Approximately 61 percent of self-propelled rail cars inspected were considered to be included in a normal maintenance program, two percent in a minimum program, 26 percent in a minimum corrective action maintenance program, and 11 percent in a major corrective action maintenance program. It can be observed in the diagram that the major corrective action maintenance program appears to provide the lowest rate of depreciation of any of the maintenance programs, although only about 11 percent of the vehicles inspected were covered by this type of program. This type of major corrective action maintenance program is based on the philosophy that when major components fail, especially those that may effect safety or operations, a standard specification is developed for the major maintenance of all rail cars in that category. This major maintenance involves completely restructuring the rail cars by tearing down each car completely, including motor, trucks, wiring, batteries, windows and everything but the body and frame; new wiring, voltage regulators, current limit relays, accelerator contact fingers, brakes, windows, etc. are then installed. However, a normal preventive maintenance program may provide about the same maximum condition for the same age with both methods having some rail cars that were 22 years old in "good" condition, 36 years old in "fair" condition, and not in "poor" condition until they were almost 60 years old.

FIGURE 3.13
VEHICLES
SELF-PROPELLED RAIL CAR CONDITION VERSUS AGE



Locomotives. The observed average or median deterioration of the locomotives is illustrated in Figure 3.14. This data indicates that the locomotives deteriorated to a "poor" condition in less than 10 to about 35 years, depending upon the type of maintenance program. Approximately 71 percent of locomotives inspected were considered to be covered by a preventive maintenance program, three percent in a minimum maintenance program and 26 percent in a maximum corrective maintenance program. As shown on the diagram, a normal preventive maintenance program provides significantly lower deterioration than either of the other observed maintenance programs; some locomotives were observed to be in a "fair" condition that were 33 years old.

Unpowered Cars. The observed average or median deterioration of unpowered cars is illustrated in Figure 3.15 and indicates that these cars depreciated to a "poor" condition in less than 30 years. Approximately 82 percent of the unpowered cars inspected were considered to be covered by a normal preventive maintenance program, two percent in a minimum program, and 16 percent in a maximum corrective maintenance program. With a normal preventive maintenance program, some of these cars did not deteriorate to a "bad" condition until they were nearly 50 years old.

FIGURE 3.14
VEHICLES
LOCOMOTIVE CONDITION
VERSUS AGE

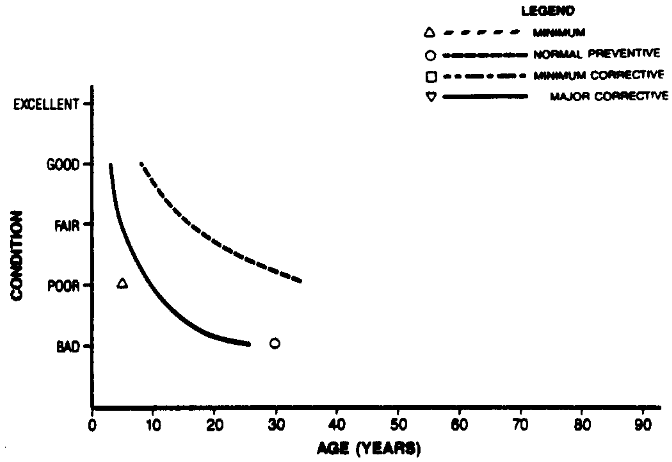
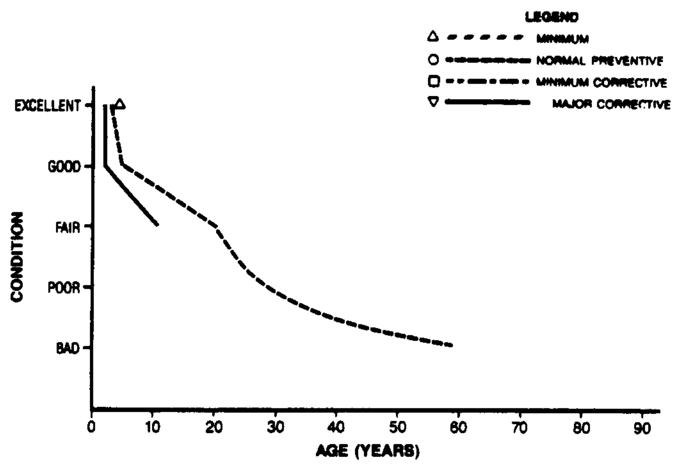


FIGURE 3.15
VEHICLES
UNPOWERED CAR CONDITION
VERSUS AGE



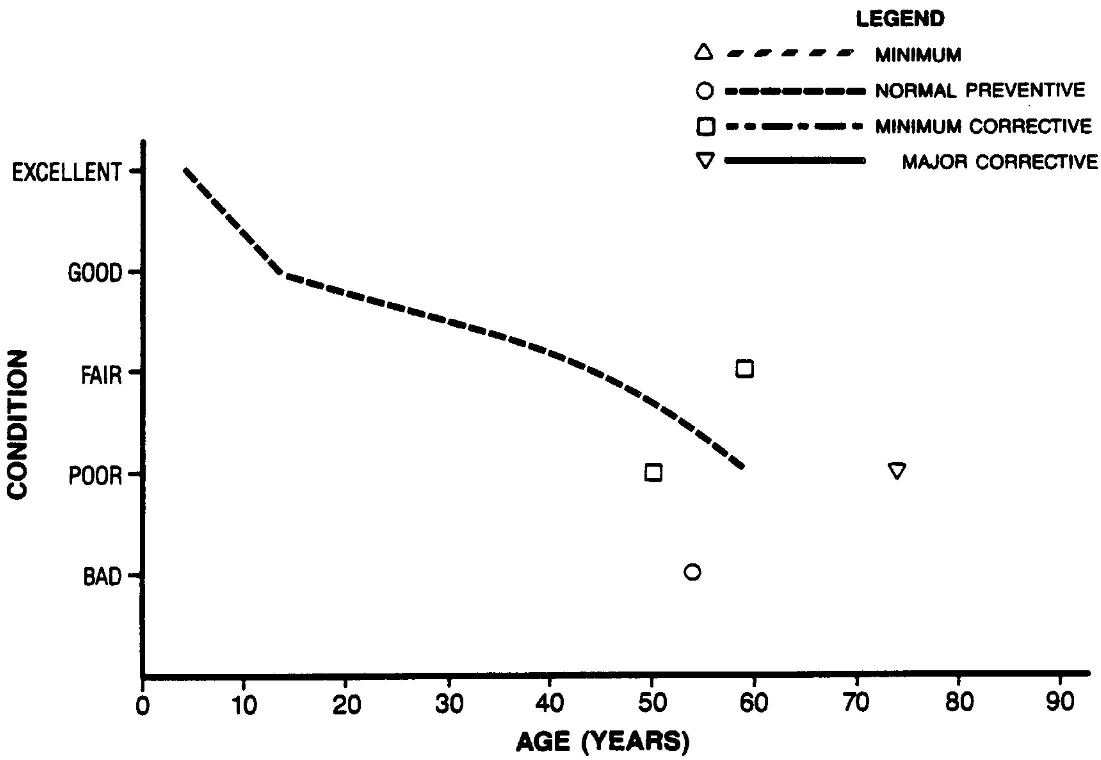
- Power Distribution. The power distribution system element deterioration was evaluated by investigating the deterioration of power substations, overhead wire, and third rail; the results are discussed in the following paragraphs:

Substations. The observed average or median deterioration of power substations is illustrated in Figure 3.16 and it can be observed that these substations deteriorated to a "poor" condition in 50 to 60 years, on the average.

Almost 91 percent of the substations inspected were considered to be included in a normal preventive maintenance program, seven percent in a minimum corrective maintenance program and only two percent in a maximum corrective maintenance program. With a normal preventive maintenance program, some of the substations were still in a "good" condition after 28 years of service, "fair" condition at almost 50 years, and did not deteriorate to a "poor" condition until they were almost 70 years old.

FIGURE 3.16

POWER DISTRIBUTION SUBSTATION CONDITION VERSUS AGE



Overhead Wire. The observed average or median deterioration of the overhead wire is illustrated in Figure 3.17 and it can be observed that the average condition is better than "poor" until the wire is almost 55 years old, with a normal preventive maintenance program. All of the inspected overhead wire was considered to be included in some type of normal preventive maintenance program.

Third Rail. The observed average or median deterioration of third rail is illustrated in Figure 3.18 and it can be observed that some of this rail did not deteriorate to a "poor" condition until it was almost 60 years old, with a normal preventive maintenance program. More than 95 percent of the third rail inspected was considered to be included in some type of normal preventive maintenance program and some of the rail was in "good" condition at age 24 and did not depreciate to a "poor" condition until it was almost 75 years old.

FIGURE 3.17
POWER DISTRIBUTION OVERHEAD WIRE CONDITION VERSUS AGE

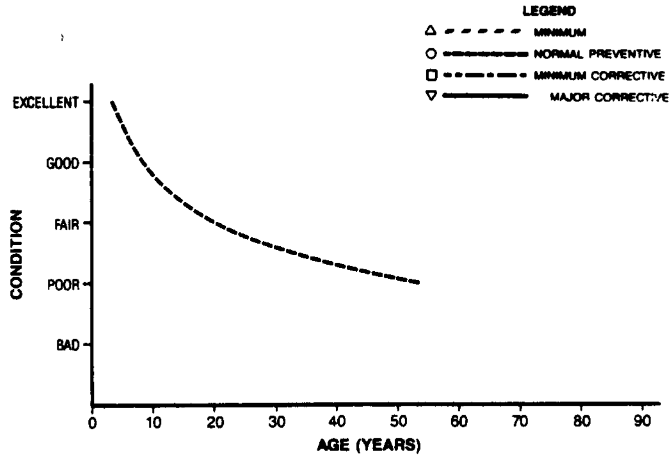
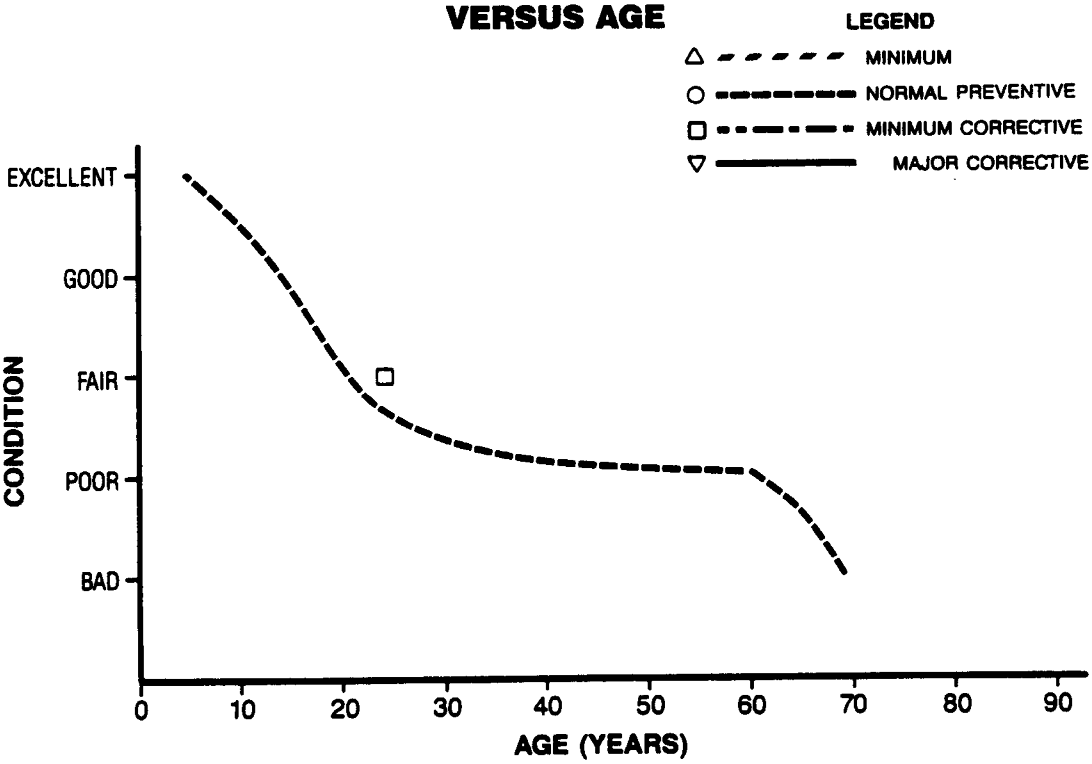
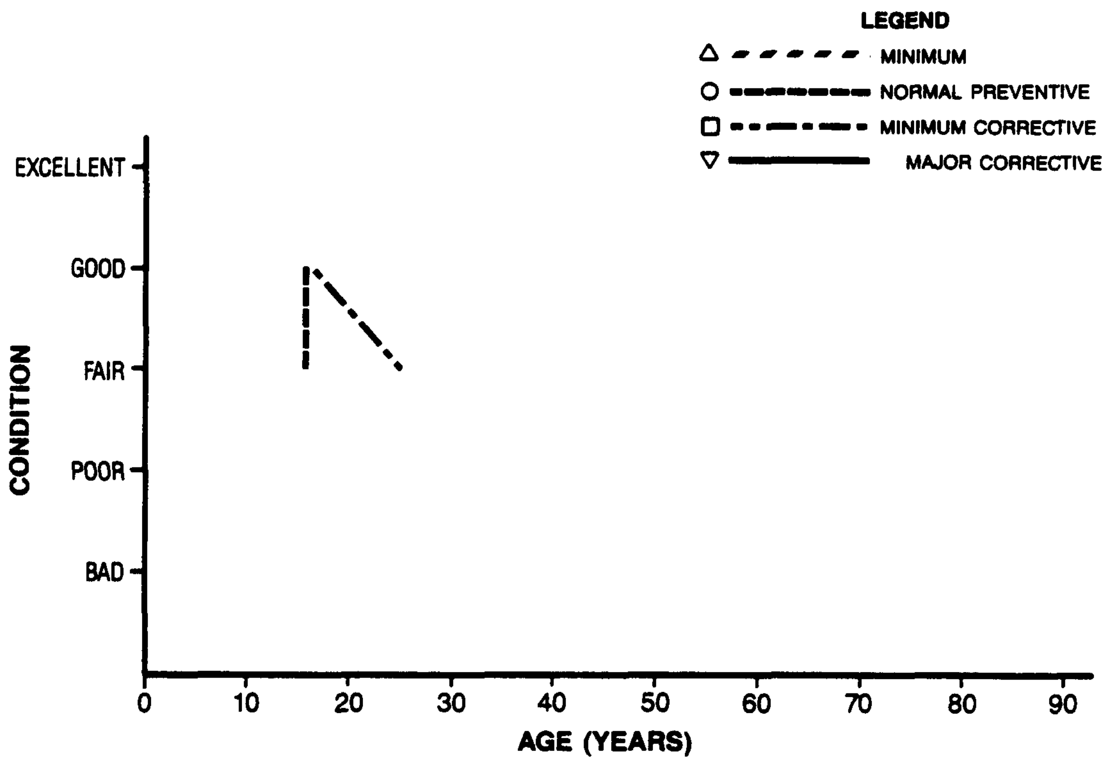


FIGURE 3.18
POWER DISTRIBUTION THIRD RAIL CONDITION VERSUS AGE



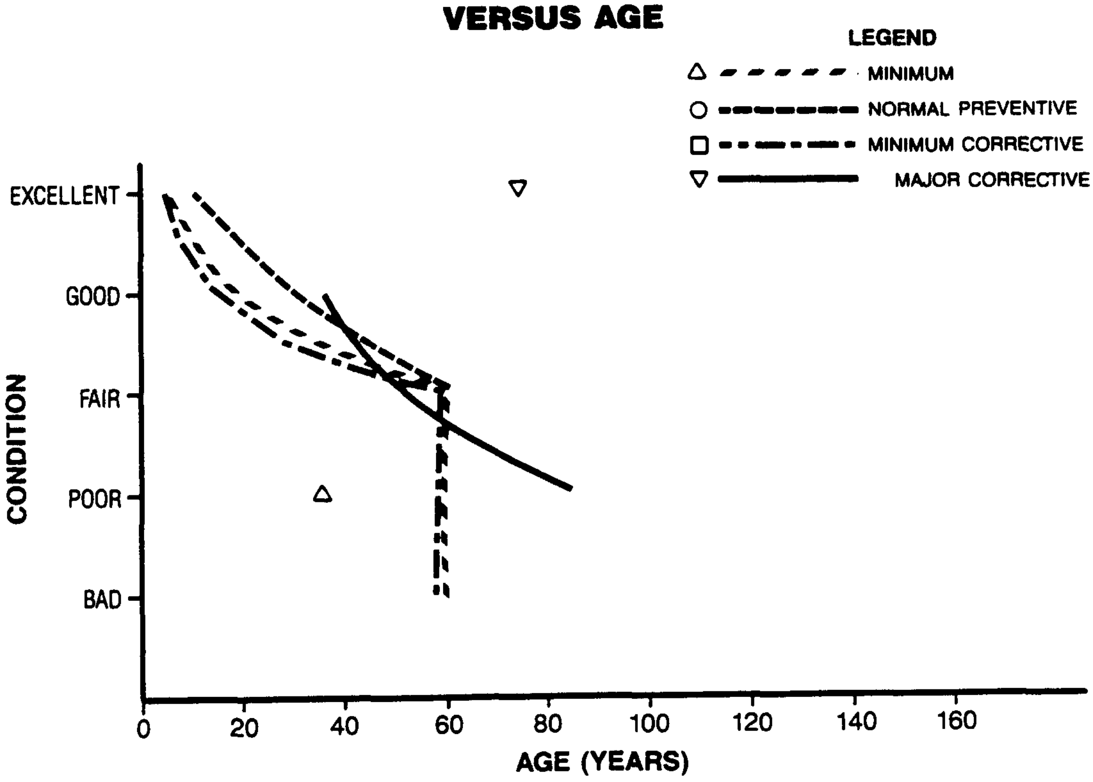
- <u>System-Wide Controls</u>. The system-wide controls system element was evaluated as a complete system and the average or median deterioration is illustrated in Figure 3.19. None of the systems inspected were considered to be in a "poor" condition. Only two types of preventive maintenance programs were observed; with 67 percent of the systems using some type of minor corrective maintenance program and 33 percent using a normal preventive maintenance program. At least some of the system-wide controls were still in a "fair" condition after 50 years of service.

FIGURE 3.19
SYSTEM-WIDE CONTROL CONDITION VERSUS AGE



- Stations. The observed average or median deterioration of the stations is illustrated in Figure 3.20 and it can be observed that most of the stations were in a "fair" condition after nearly 60 years of service. However, some of the stations were in a "poor" condition after less than 40 years, even with a normal preventive maintenance program; on the other hand, some stations were also in "good" and "fair" condition after nearly 120 years with the same type of preventive maintenance program. Approximately 40 percent of the stations inspected were considered to be included in a normal preventive maintenance program, 39 percent in a minimum program, 19 percent in a minimum corrective maintenance program and only two percent in a major corrective maintenance program. Nearly 98 percent of the station maintenance programs emphasize maintaining the aesthetic appearance of the stations.

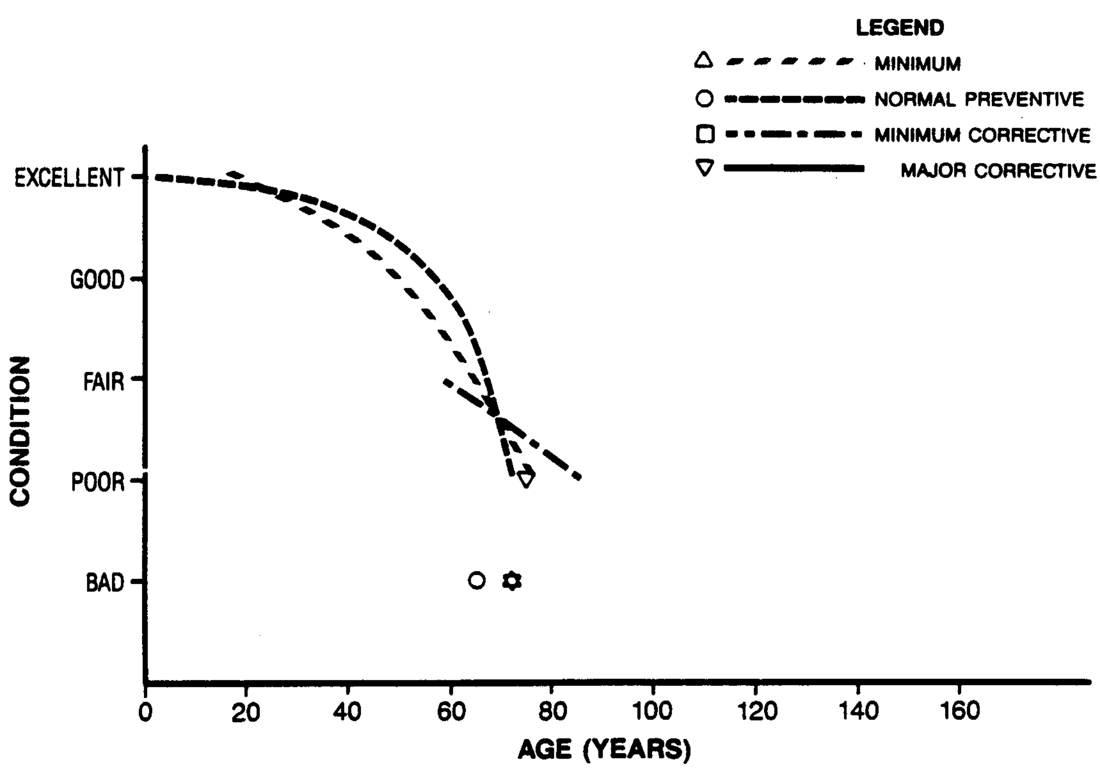
FIGURE 3.20
STATION CONDITION VERSUS AGE



- Structures and Facilities. The structures and facilities system element deterioration was evaluated by determining the deterioration of bridges and tunnels; the results are discussed in the following paragraphs:

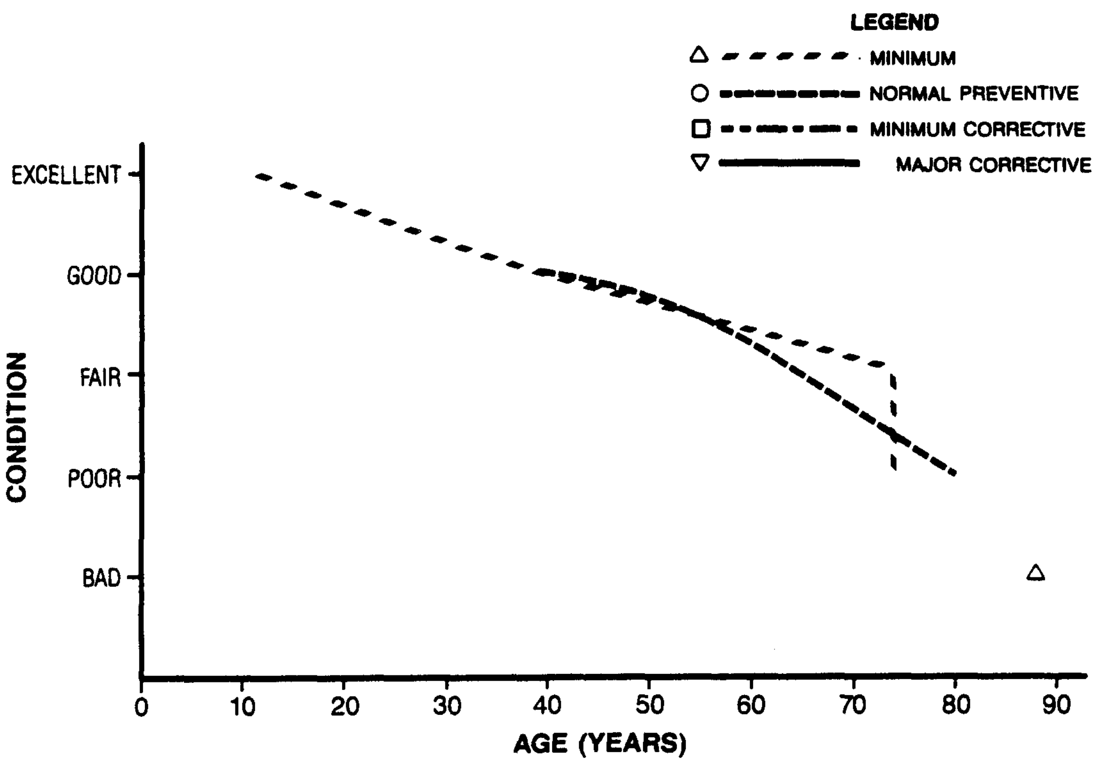
Bridges. The observed average or median deterioration of the bridges is illustrated in Figure 3.21 and it can be observed that the bridges deteriorated to a "poor" condition in 65 to 85 years, on the average. Approximately 76 percent of the bridges inspected were considered to be included in a minimum maintenance program and 23 percent in a normal preventive maintenance program. The diagram indicates that the rate of deterioration is not much different for either a minimum or normal preventive maintenance program since either program would tend to reduce the interaction caused by the weather conditions, salt spray, and other factors caused by the physical environment. With either type of preventive maintenance program, some bridges were still in "good" condition after nearly 90 years of age.

FIGURE 3.21
STRUCTURES AND FACILITIES
BRIDGE CONDITION
VERSUS AGE



Tunnels. The observed average or median deterioration of tunnels is illustrated in Figure 3.22 and it can be observed that the tunnels deteriorated to a "poor" condition in 75 to 80 years. However, some tunnels were still in fair condition after 100 years, even with only a minimum maintenance program. Approximately 67 percent of the tunnels were considered to be included in a minimum maintenance program and the remaining 33 percent in a normal preventive maintenance program.

FIGURE 3.22
STRUCTURES AND FACILITIES TUNNEL CONDITION VERSUS AGE

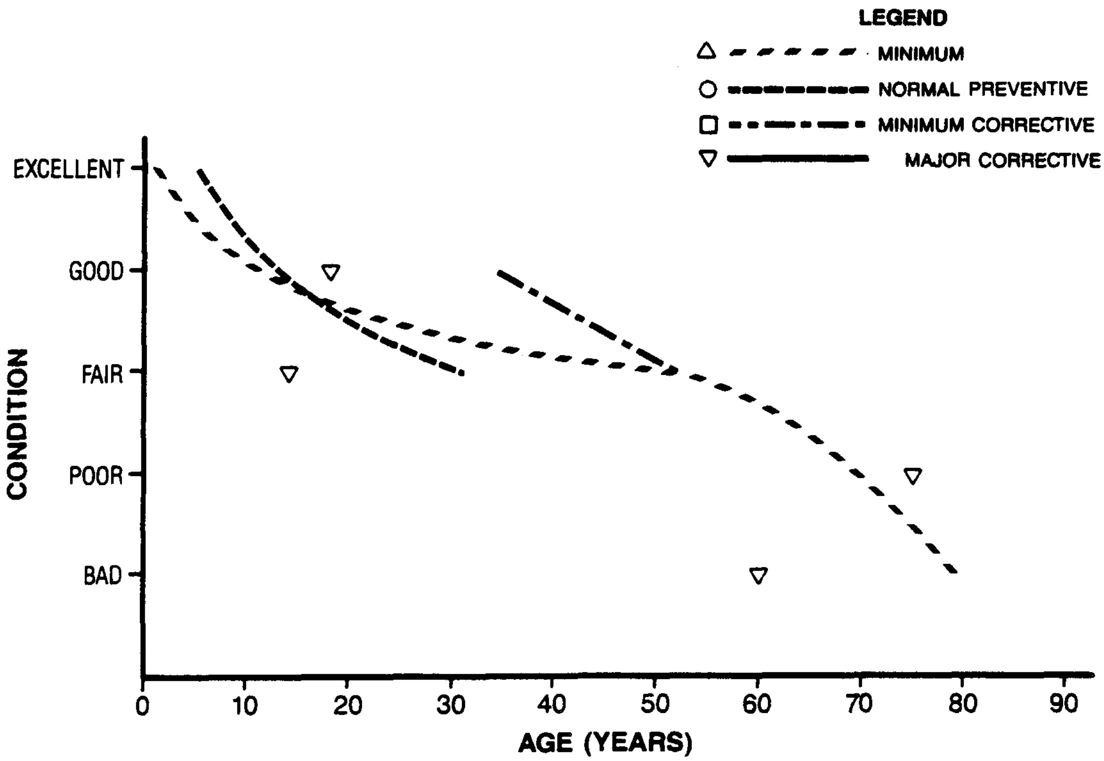


- Maintenance Facilities. The maintenance facility deterioration was evaluated by determining the deterioration of the building and maintenance/storage yards.

Maintenance Buildings. The observed average or median deterioration of the maintenance buildings is illustrated in Figure 3.23 and it can be observed that these buildings deteriorated to a "poor" condition in 70 or 75 years, even with a minimum maintenance program.

Approximately 65 percent of the maintenance facility buildings were included in some type of minimum maintenance program, 22 percent in a normal maintenance program and the remaining 13 percent equally divided between a minimum and major corrective maintenance program. Although no buildings were determined to be in a "poor" condition, with a normal preventive maintenance program, some buildings were still in "good" condition after 50 years of operation and even a "fair" condition after almost 150 years.

FIGURE 3.23
MAINTENANCE FACILITY BUILDING CONDITION VERSUS AGE

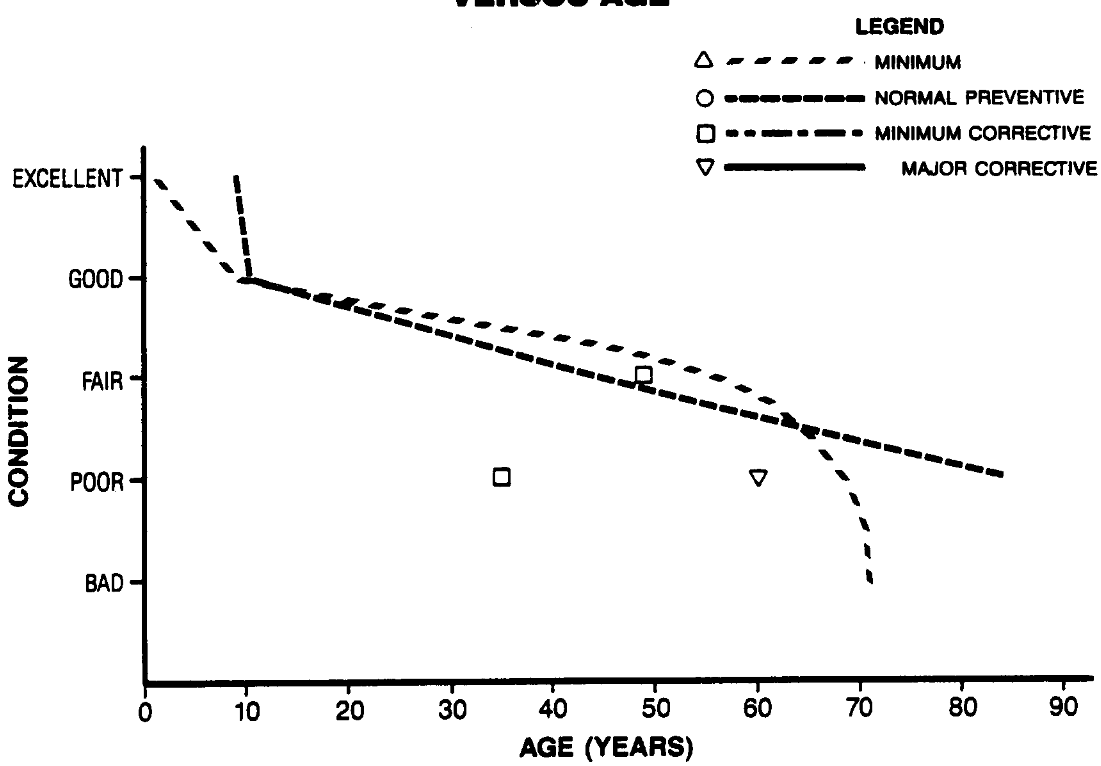


Maintenance/Storage Yards. The observed average or median deterioration of the maintenance/storage yards is illustrated in the maintenance yard condition versus age diagram and it can be observed that the yards normally deteriorated to a "poor" condition in 70 to 85 years. Approximately 64 percent of the yards inspected were considered to be included in a minimum maintenance program, 17 percent in a normal preventive maintenance program, 11 percent in a minimum corrective maintenance program and the remaining eight percent in a maximum corrective maintenance program. No yards were estimated as being in a "bad" condition when a normal preventive maintenance program was employed and one yard was still in good condition after 50 years with the same type of program.

References

[1]Statistical Analysis of Industrial Property Retirements, by Robley Winfrey, Bulletin 125, published by Engineering Research Institute of Iowa State University, Revised 1967.

FIGURE 3.24
MAINTENANCE/STORAGE YARD CONDITION VERSUS AGE



4.0 PROPOSED REPAIR AND REPLACEMENT ACTIONS

4.1 GENERAL PROCEDURE FOR ESTABLISHING THE PROPOSED LEVEL OF IMPROVEMENT

The general procedure for defining and estimating rail modernization projects was explained in Chapter 1. After the current condition was established from the physical assessment and evaluation of the performance data, the types of improvements to return all elements on all segments to good condition (if feasible) were determined and compared to the projects that had already been funded at the time of the inspection for each transit system. These already funded projects were deleted from the proposed repair and replacement actions that are explained in this chapter.

As previously explained in Chapter 2, seven levels of improvement were defined. Each level of improvement is related to an estimate of the present condition of the system element or subsystem to be improved and the category of improvement (i.e., modernization, rehabilitation, or refurbishment), as indicated in Table 4.1.

After the current condition was established, a corresponding level of improvement was determined for proposed projects that have not already been funded. As shown in Table 4.1, there are three levels of modernization (1, 2, and 4), two levels of rehabilitation (3 and 5), and two levels of refurbishment (6 and 7). Each level of improvement may involve the replacement of subsystems, components, and equipments with the type of replacement dictated by the degree of the improvement. That is, modernization is a category of rail system improvement whereby original equipment or materials are replaced with proven new equipment or materials to achieve higher levels of performance or productivity. Modernization includes the replacement of facilities and equipment which are functionally or economically obsolete with new components, subsystems, and/or entire units. Rehabilitation is a lesser category of rail system improvement than modernization whereby worn or weakened materials, components and subsystems are replaced with new parts having basically the same design or function as the original equipment. Rehabilitation includes the renovation of existing facilities or equipment, as necessary, to achieve

TABLE 4.1

Level of Improvements

Present Condition	Category of Improvement		
	Modernization	Rehabilitation	Refurbishment
Bad	Level 1	na[1]	na
Poor	Level 2	Level 3	na
Fair	Level 4	Level 5	Level 6
Good	na	na	Level 7
Excellent	na	na	na

[1]na - not applicable

original levels of service, safety, capacity or reliability. Refurbishment is a still lesser category of rail system improvement whereby existing equipment or facilities are restored to adequate levels of performance without the necessity for major replacement of parts or components. Refurbishment should result in the capacity to sustain existing system performance. In order to assist in establishing the level of improvement that was most appropriate for the present condition of the subsystem, various decision rules were developed, as explained in Section 2.3. These decision rules were evaluated to determine the "best" level of improvement when more than one level of improvement may be appropriate (e.g., when the present condition is "poor" or "fair"). Although all of the decision rules are important in selecting the appropriate level of improvement, the age and obsolescence of the equipment to be replaced are of special interest in establishing the level of improvement. For example, if the transit system is relatively new (i.e., BART and MARTA), the equipment or subsystems would be replaced by similar types of new equipment or subsystems and the category of improvement would be defined as "refurbishment". However, if the transit system is older (i.e., NYCTA and LIRR), the old equipment being replaced was usually obsolete and no longer available and has to be replaced with new equipment that should meet higher standards of productivity; this degree of improvement is defined as "modernization".

The primary differences between the different levels within the categories of modernization, rehabilitation and refurbishment are related to the present condition and number or amount of subsystems or system elements being replaced. A level 1 modernization would be chosen when the present condition of the system element is bad and it is estimated that 70 to 100 percent of the system element would be replaced, as indicated in Table 4.2. However, when the present condition is "fair", then it is estimated that only 20 to 40 percent of the equipment or subsystems would have to be replaced with equipment that would provide higher standards of productivity. In this situation, some of the remaining 60 to 80 percent of

Table 4.2

GENERAL DEFINITIONS FOR MODERNIZATION, REHABILITATION AND REFURBISHMENT

TYPE OF IMPROVEMENT	LEVEL OF IMPROVEMENT	PERCENT REPLACEMENT
MODERNIZATION	1	70%–100%
	2	40%–70%
	4	20%–40%
REHABILITATION	3	70%–100%
	5	40%–70%
REFURBISHMENT	6	10%–40%
	7	0%–10%

the equipment would not be proposed for replacement but for reworking or overhaul during the period of replacement. A level 3 improvement also implies that 70 to 100 percent of the equipment or subsystem would be replaced but not necessarily with equipment that has higher standards of productivity (the definitions only require components having the same fit and function as the original equipment). The level 5 rehabilitation implies that 40 to 70 percent of the components would be replaced with components having the same fit and function; the remaining 30 to 60 percent of the equipment could also be overhauled or reworked during the period of improvement but would not be replaced. It was estimated that refurbishment would require lower percentages of replacement, as shown in Table 4.2, but possibly higher percentages or repair/overhaul during the replacement period.

One of the major problems associated with the replacement of equipment and components is the ability to obtain these replacement parts throughout the life of the system (i.e., 30 to 100 years, depending upon the system element). As a result, some transit systems have been developing the capability to remanufacture critical spare parts that can no longer be obtained from the original supplier. As a result, the specific maintenance capability of each transit system had to be considered, as well as the decision rules explained in Section 2.3, in the assignment of proposed levels of improvement.

After each project was defined, a Project Formulation Sheet was prepared for further analysis. These sheets provided a summary of the proposed subsystem improvements for <u>each system element</u>. More than one project sheet was prepared for a particular system element when different levels of improvement were proposed. However, when several improvements to the same system element were proposed and the level of improvement was the same, only <u>one</u> Project Formulation Sheet was sometimes necessary. For example, different types of stations that were proposed for a level 6 refurbishment could all be entered on the same Project Formulation Sheet but separate entries were required.

It is important to note that each Project Formulation Sheet described improvements to individual subsystems, and the current condition and level of improvement were determined for the subsystem, not the overall element. This makes it difficult to compare current condition data from Chapter 3, which represents the overall condition of an element, to improvement projects, which include the current condition of individual subsystems that make up a given element. For example, the overall condition of a segment of track may be "good", but an improvement project could be proposed to replace several "bad" ties.

The Project Formulation Sheet provided the following information for computer analysis:

- Transit system (by name)
- Project number
- Present condition
- Condition after improvement
- Level of improvement
- Goal areas supported by the projects (all or some of the following in order of the project's importance)
  - Safety
  - Reliability and Availability
  - Operating Efficiency
  - Security
  - Aesthetics or Amenities
- Specific Project Cost Estimates (up to 11)
  - Item to be improved (e.g., rail, rail joints, ties/crossties, etc.)
  - Quantity of item
  - Unit cost of item
  - Subsystem cost
- Total cost of subsystems
  - Design contingency cost
  - Construction contingency cost (including maintenance of traffic provisions)
  - Implementation contingency cost
  - Total project cost
  - Planned cost staging (1985 to 1994)

A project description was prepared in support of each project. The project description was designed to provide a reasonable understanding of each project. The description also permitted some additional adjustments in the costs to be made, when and if necessary. Although the description was not entered in the computer, it was an essential part of the evaluation process.

The following additional comments are pertinent to the development of project descriptions for this study.

- o The project descriptions are all based on an evaluation of the current condition of each system element. That is, a project description was prepared for each section of track that was in the same condition and where the same level of improvement was proposed. However, when several improvements to the same system element were proposed and the level of improvement was the same, only one project formulation sheet was required. As a result, there may be several project descriptions within a given system element, depending upon the present condition and level of improvement for each part of the element. Thus, multiple projects are distributed throughout the ten-year period from 1985 to 1994.

- o Most transit authorities do not have ten-year capital improvement programs, and those that do would package their programs differently than was done for this study. For example, a large track project would probably include track and structure improvements and perhaps changes to the wayside signals within the scope of the project. However, this study would have at least four project descriptions (i.e., at least one track, power distribution, system-wide controls, and structure and facility project in order to analyze costs and levels of improvement).

The remainder of this chapter indicates the general findings with respect to modernization, rehabilitation, and refurbishment for each major system element and each major rail area.

4.2 SUMMARY OF LEVELS OF IMPROVEMENT BY TYPE OF TRANSIT SYSTEM FOR EACH MAJOR RAIL AREA

The primary purpose of this section of the report is to provide a summary of identified repair and replacement actions for each major rail area which would bring all rail systems to a "good" condition. The following sections describe these improvements for system elements/major subsystems by type of transit system for each of the designated major rail areas. As previously discussed, improvements are based on the existing physical condition of each system element/major subsystem. Projects which have already been funded have not been included in the improvements. In addition, proposed projects do not include:

- Rail line extensions.
- Expansion of service due to projected increases in rail ridership.
- Improvements such as multi-modal transportation centers, and major new station complexes, etc.
- Special elderly and handicapped requirements such as elevators, ramps, and high level platforms in stations that do not yet have them.
- Upgrade of abandoned station or deleted line service.

- o Track Improvements

  The track improvements for the rail transit systems which would bring all track to a "good" condition are provided in Table 4.3. It should be noted that these numbers represent equivalent miles of track improvements. Subsystems other than rail were converted to equivalent track miles being improved. Also, these projects sometimes affect the same segment more than once. For example, one project could rehabilitate a segment and a second system-wide improvement might affect the same segment. As a result, the number of equivalent miles of improvements shown in Table 4.3 may be greater than the actual miles of track in the system.

The rapid rail systems have a total of 456 equivalent miles of track that would receive modernization, rehabilitation, or refurbishment, with most of this track being in the New York (61 percent) area. The light rail systems have 134 equivalent miles of track improvements and most of this track is in the Philadelphia area (57 percent). The commuter rail systems have 2,215 equivalent miles of track improvements, with the New York, Boston and Chicago areas requiring the most track improvements (60 percent, 16 percent and 13 percent, respectively).

A discussion of the proposed improvements in each of the major rail areas follows:

- BOSTON

  The rapid rail system includes 17 equivalent miles of track that

TABLE 4.3

TRACK IMPROVEMENTS (Miles)

Major Rail Areas	Rapid Rail				Light Rail				Commuter Rail			
	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	12	1	4	17	4	-	2	6	141	34	171	346
New York	254	20	6	280				NA	383	558	391	1332
Northern NJ	2	-	42	44	-	-	-	None	-	113	44	157
Southern NJ	1	-	2	3				NA				NA
Philadelphia	-	37	1	38	-	76	-	76	84	-	1	85
Pittsburgh				NA	24	-	-	24	-	-	6	6
Washington, DC	-	-	-	None				NA				NA
Chicago	29	9	7	45				NA	268	12	9	289
Cleveland	20	-	1	21	-	-	2	2				NA
Atlanta	-	-	3	3				NA				NA
New Orleans				NA	13	-	-	13				NA
San Francisco	-	-	5	5	8	-	-	8				NA
San Diego				NA	-	-	5	5				NA
TOTAL	318	67	71	456	49	76	9	134	876	717	622	2215

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

would require improvement. Approximately 12 miles requires a level 2 modernization. A level 3 rehabilitation was proposed for 1 mile. These improvements would include new fasteners and rail anchors. A level 7 refurbishment was proposed for approximately 4 equivalent miles of track and this improvement would include rail grinding and resurfacing. These improvements would complete the rehabilitation of the Blue and Orange Lines and result in a new track structure for the entire Red Line. Rail grinding is necessary to improve the ride quality and to decrease the rate of deterioration of the track structure; it would also remove the surface defects.

The light rail system includes 6 equivalent miles of track that would require improvement. A level 2 modernization was proposed for approximately 4 miles. This improvement would complete the renewal of all Green Line track. An additional 2 miles were proposed for a level 7 refurbishment, which includes surface grinding. It was also proposed that all mainline running rail would receive surface grinding to remove the defects.

The commuter rail system includes 346 equivalent miles of track improvements. Of this track, 5 miles would receive a level 1 modernization. An additional 136 equivalent track miles would receive a level 2 or level 4 modernization, and a level 5 rehabilitation was proposed for another 34 equivalent miles of track. The remaining 171 miles was proposed for a level 6 refurbishment. Improvements would include the replacement of rail with CWR; field welding of bolted joints; installing new adhesive-type insulation joints, and spring clip type rail fasteners; installing sawn timber ties; undercutting and adding ballast, lining and surfacing approximately 178 track miles; installing filter fabric on the New Hampshire Mainline; replacing worn and defective components on turnouts; and providing additional cleaning and rail grinding on the entire system.

- NEW YORK

The rapid rail systems include 280 equivalent miles of track that would require improvement. Of this track, 254 equivalent miles would receive a level 2 or 4 modernization. An additional 20 miles would be rehabilitated, and the remaining 6 miles would receive a level 7 refurbishment. Proposed improvements include the replacement of older 100 lb/yd rail; field welding of bolted joints; installing new adhesive-type insulation joints; installing spring clip type rail fasteners; installing new sawn timber ties; converting approximately 117 miles of type 1 track (wood ties and ballast with a concrete invert) to type 2 track (wood ties embedded in a concrete invert); replacing obsolete switches with new switches; replacing worn and defective components of the AREA switches; undercutting, lining and surfacing ballasted track. It was also proposed to stabilize the roadbed embankments and repair erosion damage; cleaning and reshaping the ditches; cleaning the inlets and making drainage repairs as required; and replacing some security fencing.

The commuter rail systems include 1,332 equivalent miles of track improvements. Of this amount, 383 equivalent miles requires modernization. Rehabilitation is proposed for 558 equivalent miles and refurbishment for 391 equivalent miles. Track improvements include some rail replacement; replacement of bolted track with continuous welded track; brush cutting and adding fencing and the installation of all new rail and turnouts in the area of Harold Interlocking. It was also proposed that several other interlockings be rebuilt to increase the speed and reduce the congestion through these interlockings.

- NORTHERN NEW JERSEY

The rapid rail system includes 44 equivalent miles of track improvements. Approximately 2 miles was proposed for a level 4 modernization; the remaining 42 miles was proposed for a level 6 refurbishment. The proposed improvements included cleaning the ballast and replacing rail and turnouts as necessary.

The light rail track required no improvements.

The commuter rail system includes 157 equivalent miles of track improvements. 113 equivalent miles of this requires a level 5 rehabilitation. The remaining 44 equivalent miles would receive a level 7 refurbishment.

- SOUTHERN NEW JERSEY

The rapid rail system includes only 3 equivalent miles of track improvements. Of this track, 1 mile should receive a level 4 modernization and the remaining 2 miles should receive a level 7 refurbishment. The proposed improvements include the replacement of 132 lb/yd rail as required, spot replacement of insulated joints, and conversion to spring type rail fastening systems for the rail and/or ties as they are to be replaced; replacement of approximately 5,300 ties annually and replacement of special trackwork components as required.

- PHILADELPHIA

The rapid rail system includes 38 equivalent track miles that would require improvement. Of this track, approximately 37 miles would receive a level 5 rehabilitation and the remaining 1 mile requires only a level 7 refurbishment. Proposed improvements include replacement of bolted rail with continuous welded rail, replacement of defective timber tie blocks and crossties, replacement of ballast and replacement of defective special trackwork rail and components as required.

The light rail system includes 76 equivalent track miles that would require improvement. Of this track, 66 equivalent miles would receive a level 3 rehabilitation and the remaining 10 miles would receive a level 5 rehabilitation. These improvements include replacement of existing bolted rail with 115 lb/yd CWR and installing "H" shaped resilient fasteners. Tie and ballast renewal, and track surfacing and undercutting would also be performed.

The commuter rail system includes 85 equivalent miles of track improvements. Approximately 84 miles of this was proposed for a level 4 modernization. A level 7 refurbishment was proposed for the remaining 1 mile.

Improvements include replacement of running rail, which has excessive defects, with new shop welded CWR. For short segments, field welded CWR was suggested. Installation of spring clip type fasteners with newly installed CWR was also proposed. In addition, all defective and worn turnout components were recommended for replacement and crossties on both mainline and in the yards would be replaced, as required. In the areas where the existing rail is to be retained, some of the track should be ground, resurfaced and aligned as necessary. Other improvements to the earthwork, drainage, and vegetation control were proposed.

- PITTSBURGH

The light rail system includes 24 equivalent miles of track that would require a level 4 modernization. This modernization includes the replacement of the existing bolted rail with new CWR; the renewal of rail fasteners and anchors; replacement of defective sawn timber ties; cleaning the ballast and adding new crushed stone ballast as required, replacement of all worn and/or defective switches and adding switch heaters and rail lubricators where needed; aligning and surfacing the new track, and renewal of grade crossing surfaces.

The commuter rail system includes only 6 equivalent miles of track requiring a level 7 refurbishment. Improvements include the conversion of manually operated switches to electric operation and then incorporating these switch controls into a signal/control system; field welding the mainline bolted rail; and cleaning and reshaping the ditches and installing high chain-link fencing along the parapets of the overhead bridges; and installing full gates and flasher protection at selected grade crossings.

- WASHINGTON, DC

The rapid rail system's track was all in "excellent" condition and only normal maintenance is required.

Since track on the commuter rail system is not being maintained by the Maryland Department of Transportation, proposed improvements are not applicable.

- CHICAGO

The rapid rail system includes 45 equivalent miles of track that would require improvement. Of this track, 38 equivalent miles would receive either modernization or rehabilitation. Remaining track would require either a level 6 or level 7 refurbishment. Proposed improvements include replacement of worn bolted rail with 115 lb/yd CWR; field welding of existing joints; installing new adhesive-type insulated rail joints; replacing sawn timber ties; adding additional ballast as required; realigning and resurfacing 15 track miles; worn components with special trackwork should be replaced in some locations; crushed stone ballast should be cleaned and replaced; chain-link fencing should be relocated; and automatic fence gates should be installed at some existing grade crossings to limit the access to the right-of-way.

The commuter rail systems include 289 equivalent miles of track which would be improved. 268 equivalent miles would receive modernization, 12 miles would be rehabilitated, and the remaining 9 miles were proposed for refurbishment. Typical improvements include the replacement of existing bolted rail with 115 lb/yd CWR; replacement of sawn timber ties; undercutting the ballast and adding new ballast as required; installing automatic barriers at selected grade crossings; and grinding the track as required.

- CLEVELAND

The rapid rail system includes 21 equivalent miles of track improvements. 20 equivalent miles should receive a level 2 or level 4 modernization and the remaining 1 mile should receive a level 7 refurbishment. These improvements should include the replacement of worn rail as well as grinding of the rail.

The light rail system has 2 equivalent miles of track requiring a level 7 refurbishment.

- ATLANTA

The rapid rail system includes 3 equivalent miles of track requiring a level 7 refurbishment. Typical improvements include the continued upgrading of the direct fixation fasteners and cutting "toe benches" in the tunnels where the slab configuration exposes the direct fixation fasteners to water running on the concrete.

- NEW ORLEANS

The light rail system includes 13 equivalent miles of track requiring improvement. All of this track was proposed for a level 4 modernization. Typical improvements include track modernization in the downtown area and the replacement of the pavement-embedded rail along St. Charles Avenue and around Lee Circle with girder and girder grooved CWR. The installation of new pavement embedded CWR rail parallel to the existing track on St. Charles Avenue was also proposed. The insulation of a terminal diamond crossover between the two tracks along St. Charles Avenue near Canal Street also appears to be required. The track modernization of the neutral ground was also proposed, including the replacement of nearly 22 miles of rail with 115 lb/yd tee rail CWR and spring clip type rail fasteners. The replacement of 9 single crossovers and 1 diamond crossover with new streetcar type switches was also proposed.

- SAN FRANCISCO

The rapid rail system includes 5 equivalent track miles that would require a level 7 refurbishment. Typical improvements include some rail replacement and installing running rail in those locations within the system which need rail replacement due to excessive wear. In order to keep maintaining the track in its current condition, some additional track maintenance equipment was also recommended.

The light rail system includes only 8 equivalent miles of track requiring modernization. The improvement essentially involves the reconstruction of track on a K Line between Metro Center and Juniper Serra Boulevard on Ocean Avenue. Additional improvements included the reconstruction of some turnbacks, installing double crossovers, and a turnaround loop at the end of Market Street Subway at Embarcadero Station.

- SAN DIEGO

The light rail system includes 5 equivalent track miles of improvements, for which a level 6 refurbishment was proposed. These improvements include some grade crossing and mainline track renewal, correcting track settlement problems by making a ballasted lift and surfacing the track; installing filter fabric in the areas of particularly bad track settlement; replacing running and restraining rails on the right radius curves which are wearing at an accelerated rate; replacing bolted rail with CWR at 2 bridge locations; and replacing timber ties as they wear out.

o Vehicles - Self-Propelled Rail Car Improvements

The proposed self-propelled rail car improvements for the rail transit systems are provided in Table 4.4. The rapid rail systems have 10,803 self-propelled rail cars that would require modernization, rehabilitation or refurbishment, to be in "good" or better condition (where feasible) at the end of the 10-year period, with most of these vehicles being located in New York (54 percent) and Chicago (31 percent). The light rail systems have approximately 802 vehicles that would require some type of improvement during the 10-year period and of these 40 percent are located in Philadelphia

TABLE 4.4

VEHICLES - SELF-PROPELLED RAIL CAR IMPROVEMENTS (Each)

	Rapid Rail				Light Rail				Commuter Rail			
Major Rail Areas	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	-	72	262	334	100	-	-	100	30	-	-	30
New York	-	3604	2234	5838				NA	-	1500	-	1500
Northern NJ	209	-	90	299	-	-	24	24	33	230	-	263
Southern NJ	-	181	-	181				NA				NA
Philadelphia	-	125	369	494	162	155	-	317	301	-	-	301
Pittsburgh				NA	31	-	4	35				NA
Washington, DC	-	-	224	224				NA				NA
Chicago	1626	704	1040	3370				NA	-	419	-	419
Cleveland	-	-	-	None	-	-	96	96				NA
Atlanta	-	-	-	None				NA				NA
New Orleans				NA	-	-	-	None				NA
San Francisco	63	-	-	63	-	230	-	230				NA
San Diego				NA	-	-	-	None				NA
TOTAL	1898	4686	4219	10803	293	385	124	802	364	2149	-	2513

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

and 29 percent in San Francisco. The commuter rail systems have approximately 2,513 self-propelled rail cars that would require improvement and 60 percent of these are located in New York, 12 percent in Philadelphia and 17 percent in Chicago. In some situations, rail cars may require more than one type of improvement during these 10 years due to the rate of depreciation and deterioration discussed in Section 2.4 of this report. As a result, the number of self-propelled rail cars which would require improvement during this 10-year period may be greater than the total number of vehicles presently owned by the different transit authorities.

A discussion of the proposed improvements in each of the major rail areas follows:

- BOSTON

  The rapid rail system includes 334 rail cars that would require some type of improvement. Of this 334, 144 rail cars are in "fair" condition and 190 are in either "good" or "excellent" condition. The cars in "good" and "excellent" condition would require a level 6 refurbishment at some time during this 10-year period. Also, the cars in "fair" condition may require various levels of additional improvement during this period, including a level 3 rehabilitation for approximately 72 rail cars and a level 6 refurbishment for the remaining cars. The refurbishment would include the replacement of one or more major assemblies (traction motors, brake calipers, motor couplings) with new or rebuilt equipment of the same design. The rehabilitation would be planned to replace the major subsystems (trucks, propulsion, air brakes) and upon completion of the rehabilitation program, a refurbishment program should also be planned at approximately 5-year intervals.

  The light rail system would require the modernization or acquisition of approximately 100 light rail cars. Although 216 rail cars are presently used in the light rail system, these rail cars are in such poor condition that their replacement would be required by 1990.

  The commuter rail system has 30 self-propelled rail cars that would require modernization. At the present time, the commuter rail system has 46 self-propelled rail cars that are in "bad" condition. A phase 3 RDC conversion for these old rail diesel cars is planned and proposed for 30 cars.

- NEW YORK

  The rapid rail system has approximately 5,838 self-propelled rail cars that would require some type of improvement during the next 10 years. At the present time, the rapid rail system has 6,314 self-propelled rail cars, of which 2,117 are in "bad" condition, 1,684 in "poor" condition and 988 in "fair" condition. New car procurements are presently underway to replace some of the older cars. As a result, approximately 3,604 cars would require rehabilitation and 2,234 cars would require refurbishment during this 10-year period. This rehabilitation and refurbishment program will last throughout the study period from 1984 to 1992, with various numbers of cars being rehabilitated and refurbished nearly every year.

The commuter rail system would require the improvement of approximately 1,500 self-propelled rail cars during this period from 1984 to 1993. At the present time, the commuter rail system has 1,406 self-propelled rail cars; 52 of which are in "bad" condition, 408 in "poor" condition, 780 in "fair" condition, and the remainder in "good" or "excellent" condition. Although some of the older rail cars have already been scheduled for retirement and an additional 174 self-propelled rail cars are on order, the remaining rail cars would require several rehabilitations during the 10-year period.

- NORTHERN NEW JERSEY

The rapid rail system would require approximately 299 self-propelled rail cars to be modernized or refurbished during this 10-year period. At the present time, the rapid rail system has approximately 283 self-propelled rail cars and 34 of these are in "poor" condition, 159 in "fair" condition and 90 in "good" condition. The rail cars in "poor" condition are already scheduled for replacement and the remaining rail cars would be rehabilitated or refurbished several times during the 10-year periods.

The light rail system has 24 self-propelled rail cars that would require refurbishment during this 10-year period. These cars are all in "fair" condition at the present time. Although these cars are 30 to 37 years old, they can be refurbished to increase their remaining life. This refurbishment would include improvements to the doors and stepwells, windshield moldings, sashes, undercoatings, truck axles, bearings, rings and pistons, bolsters, and painting.

The commuter rail system has 263 self-propelled rail cars that would require improvement during the 10-year period. At the present time, this system has 527 self-propelled rail cars and 227 of these are in "poor" condition and the remaining in "good" condition. 190 of the cars in "poor" condition will be retired. An additional 33 should receive a level 2 modernization commencing in 1985. The remaining cars should receive a level 5 rehabilitation commencing in 1988.

- SOUTHERN NEW JERSEY

The rapid rail system has 181 self-propelled rail cars that would require rehabilitation during this 10-year period. Although 46 of these are presently in "good" condition, a level 5 rehabilitation was recommended to commence in 1986. The 64 cars in "poor" condition would receive a level 3 rehabilitation, which would be completed prior to 1990. A level 5 rehabilitation was then recommended to commence in 1990 on some of the older cars.

- PHILADELPHIA

The rapid rail system has 494 self-propelled rail cars that would require some type of improvement during the study period. At the present time this system has 369 cars and 244 of these are in "poor" condition and the remaining cars are in "excellent" condition. The rail cars in "poor" condition would receive a level 6 refurbishment commencing in 1988 and rehabilitation during the period from 1992 to 1993. The rail cars that are presently in "excellent" condition would also receive a level 5 rehabilitation commencing during the 1982 to 1993 time frame.

The light rail system has 317 self-propelled rail cars that would require some type of improvement during this 10-year period. This system presently has 293 cars and 85 of these are in "poor" condition, 67 in "good" condition, and 141 in "excellent" condition. The self-propelled rail cars in "poor" condition should all receive a level 1 or level 2 modernization commencing by 1985. The rail cars in "good" condition should receive a level 1 modernization beginning in 1989. The rail cars in "excellent" condition should also receive a level 5 rehabilitation commencing after 1986.

The commuter rail system has 301 self-propelled rail cars which would require improvement during this study period. This system has 343 self-propelled cars and 33 of these are in "bad" condition, 5 in "poor" condition, 54 in "fair" condition and the remaining cars are in "excellent" or "good" condition. The rail cars in "bad" condition would all require a level 1 modernization. Some of the rail cars in "poor" and "fair" condition are presently receiving a level 3 rehabilitation, which has already been funded. In addition, the rail cars in "good" condition should receive a level 2 or level 4 modernization commencing in 1988.

- PITTSBURGH

The light rail system has 35 self-propelled rail cars which would require some type of improvement during the study period. At the present time, this rail system has 75 cars that are in "bad" condition and 8 cars that are in "excellent" condition. It is recommended that the cars in "excellent" condition receive a level 6 refurbishment commencing in 1993. Some of the level 2 modernization of the cars in "bad" condition has already been partially completed. As a result, only 31 cars in the modernization programs have not yet been funded.

- WASHINGTON, DC

The rapid rail system has 224 self-propelled rail cars which should receive a refurbishment during this study period. The rapid rail system includes 316 rail cars and 298 of these cars are in "good" condition and the remaining 18 are in "excellent" condition. A level 7 refurbishment was proposed for 224 of these cars.

- CHICAGO

The rapid rail system contains 3,370 self-propelled rail cars that would require some type of improvement during this study period. At the present time, the Chicago rapid rail system has 1,148 cars and 560 of these are in "bad" condition, 144 in "poor" condition, 46 in "fair" condition and the remaining in either "excellent" or "good" condition. A level 1 modernization was proposed for all of the cars in "bad" condition and a level 3 rehabilitation was proposed for the cars in "poor" condition. Also proposed was that the cars in "fair" condition receive a level 4 modernization and the cars in "good" and "excellent" condition receive a level 3 rehabilitation commencing during the period from 1986 to 1994. Only some of the cars being modernized would require refurbishment near the end of this 10-year period.

The commuter rail system has 419 self-propelled rail cars which would require some type of improvement during this study period. At the present time, the commuter rail system has 209 self-propelled rail cars and 129 of these are in "fair" condition, 36 in "good" condition and 44 in "excellent" condition. The cars in "fair" condition would require rehabilitation commencing within the next 2 years. The cars in "good" and "excellent" condition would also require rehabilitation during the study period.

- CLEVELAND

The rapid rail system presently has 98 self-propelled rail cars which are in either "poor" or "bad" condition; these cars are all being replaced and funding has already been obtained. As a result, no improvements are required.

The light rail system would require 96 vehicles to receive some type of improvement during the next 10 years. At the present time the light rail system has 68 self-propelled rail cars and 20 of these are in "fair" condition and the remaining 48 in "excellent" condition. All of these cars would require some type of refurbishment during the period from 1985 to 1994.

- ATLANTA

The rapid rail system has 120 new self-propelled rail cars and all of these are in "good" condition. As a result, no improvements are required during this 10-year period.

- NEW ORLEANS

The light rail system has 35 self-propelled rail cars and all of these are in "fair" condition and presently receiving modernization and rehabilitation that has already been funded. As a result, no improvements are required during this study period.

- SAN FRANCISCO

The rapid rail system has 63 self-propelled rail cars which would require some type of improvement during the 10-year period. Although all of the present 439 cars are in "good" condition, an additional 150 C-Cars have been ordered; all but 63 of these cars have already been funded.

The light rail system has 230 self-propelled rail cars which would require some type of rehabilitation during the next 10 years. Although this system has 130 rail cars which are all in "good" or "excellent" condition, a level 5 rehabilitation would be required commencing in 1986. The newer cars would also require a level 5 rehabilitation commencing in 1991.

- SAN DIEGO

The light rail system has 24 new self-propelled rail cars, all of which are in "good" condition. As a result of the present maintenance program, no capital investment should be required during the 10-year period.

o Vehicles - Locomotive and Unpowered Car Improvements

The proposed improvements to the commuter rail locomotives and unpowered cars to leave all in "good" or better condition at the end of the 10-year period are provided in Table 4.5. The commuter rail systems have approximately 395 locomotives that would require some type of modernization, rehabilitation or refurbishment during the 10-year period from 1985 to 1994. Most of these locomotives are located on the Chicago commuter rail systems. There are also 1,633 unpowered cars that would require some type of improvement during the study period and approximately 74 percent of these are located on the Chicago commuter rail systems.

A discussion of the proposed improvements in each of the major rail areas follows:

- BOSTON

The commuter rail system has 34 locomotives that would require modernization and 36 that would require rehabilitation during the study period. In addition, 100 unpowered cars would require modernization and 59 would require refurbishment during the period from 1985 to 1994. At the present time, the commuter rail

TABLE 4.5

VEHICLES - LOCOMOTIVE AND UNPOWERED CAR IMPROVEMENTS (Each)

Major Rail Areas	Locomotives				Unpowered Cars			
	MO	RH	RF	T	MO	RH	RF	T
Boston	34	36	-	70	100	-	59	159
New York	12	68	-	80	1	29	-	30
Northern NJ	16	13	27	56	152	-	-	152
Southern NJ				NA				NA
Philadelphia				NA				NA
Pittsburgh	-	2	-	2	-	10	-	10
Washington, DC	5	5	-	10	39	22	-	61
Chicago	37	134	-	171	-	62	1149	1211
Cleveland				NA				NA
Atlanta				NA				NA
New Orleans				NA				NA
San Francisco	6	-	-	6	10	-	-	10
San Diego				NA				NA
TOTAL	110	258	27	395	302	123	1208	1633

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment

T - Total NA - Not Applicable

system has a total of 37 locomotives and 19 of these are in "poor" condition and the remaining 18 are in "good" condition. The 19 locomotives in "poor" condition would all require a level 1 modernization. The 18 locomotives in "good" condition would require a level 5 rehabilitation. In addition, it is planned to purchase 27 new locomotives at some time after 1987. The commuter rail system presently has 157 unpowered cars and 23 of these are in "bad" condition, 60 are in "good" condition and the remaining 74 are in "excellent" condition. The unpowered cars in "bad" condition should receive a level 2 modernization. The unpowered cars in "good" condition should receive a level 6 refurbishment. In addition, it is presently planned to purchase 45 new unpowered cars, possibly Gallery types.

- NEW YORK

The commuter rail systems have 80 locomotives and 30 unpowered cars that would require some type of improvement during the period from 1985 to 1994. Although this commuter rail system presently has 135 locomotives, some of the locomotives will be retired and some of the rehabilitations have already been funded. The remaining vehicles in "fair" condition should receive a level 5 rehabilitation. The commuter rail system also has 389 unpowered cars and 82 of these are presently in "poor" condition, 290 are in "fair" condition and the remaining cars in either "good" or "excellent" condition. Most of these cars are already scheduled for a level 3 or level 5 rehabilitation, which has been funded. The remaining unpowered cars should receive a level 3 rehabilitation. At least 1 of the unpowered cars would require modernization during the 10-year period being considered.

- NORTHERN NEW JERSEY

The commuter rail system has 56 locomotives and 152 unpowered cars that would require some type of improvement during the next 10 years. The commuter rail system presently has 86 locomotives and 13 of these are in "poor" condition, 46 are in "fair" condition, and the remaining 27 are in "good" condition. A level 2 modernization has been proposed for 4 of the locomotives in "poor" condition. In addition, the procurement of additional diesel-electric/electric locomotives would allow for direct New York City connection for trains now stopping in Newark. An additional refurbishment of 27 locomotives during this 10-year period is also proposed. The 56 unpowered cars in "poor" condition are all scheduled for retirement. In addition, the 152 unpowered cars in "fair" condition are receiving a level 4 modernization, some of which has already been funded.

- PITTSBURGH

The commuter rail system presently has 2 locomotives which are in "good" condition and 10 unpowered cars which are also in "good" condition. The 2 locomotives should receive a level 5 rehabilitation, commencing in 1986. The 10 unpowered cars should receive a level 5 rehabilitation, commencing in 1991.

- WASHINGTON, DC

The commuter rail system has 10 locomotives which would require some type of improvement during the study period and 61 unpowered cars which would require either modernization or rehabilitation during this time frame. At the present time, the commuter rail system has 6 locomotives which are in "good" condition. 5 of the locomotives in "good" condition should receive a level 5 rehabilitation commencing in 1993. In addition, it is planned to procure 2 modern locomotives in 1985 and to procure 3 additional locomotives to replace the aging RDC cars in 1989. The 22 unpowered cars are all in "good" condition, but should receive a level 2 modernization commencing in 1986. In addition, a level 5 rehabilitation is proposed for the 1994 time frame. Some additional unpowered cars will also be required to replace the aging RDC cars.

- CHICAGO

The commuter rail system has 171 locomotives and 1,211 unpowered cars that would require some type of improvement during the 10-year period. At the present time, Chicago has 126 locomotives and 37 of these are in "fair" condition and 89 are in "good" condition. The 37 locomotives in "fair" condition would all require some type of modernization during this 10-year period. In addition, the 89 locomotives in "good" condition would require some type of rehabilitation. Of the present 695 unpowered cars, 81 of these are in "fair" condition and 614 are in "good" condition. Most of the cars in "fair" condition would require some type of rehabilitation. The remaining cars would require refurbishment at approximately 5 to 6 year intervals.

- SAN FRANCISCO

The commuter rail system would require 6 locomotives and 10 unpowered cars to be modernized during the 10-year period. At the present time, the commuter rail system has 24 locomotives and 11 of these are in "bad" condition, 10 in "fair" condition and 3 in "good" condition. The proposed improvements include the purchase of 18 new diesel electric locomotives, commencing in 1985; all but 6 of these have already been funded. The commuter rail system also has 73 unpowered cars and 27 of these are in "bad" condition, 31 in "poor" condition and 15 in "fair" condition. Modernization and rehabilitation of most of the vehicles in "poor" condition has already been funded. As a result, only 10 of these unpowered cars should require a level 1 modernization during the study period.

o Power Distribution - Substation Improvements

The proposed substation improvements for the rail transit systems to leave all in "good" or better condition at the end of the 10-year period are provided in Table 4.6. It should be noted that these numbers represent the number of equivalent substation improvements. Each subsystem proposed for improvement was converted to the number of equivalent substations being improved. Alsc, these projects sometimes affect the same substation more than once. For example, one improvement project could rehabilitate a substation, and a second system-wide refurbishment might affect the same substation. As a result, the number of equivalent substations shown in Table 4.6 may be greater than the actual number of substations in the system.

The rapid rail systems have a total of 434 equivalent substations requiring improvement, with most of these substations being located in New York (61 percent) Chicago (11 percent), and Washington, D.C. (16 percent). The light rail systems have only 13 equivalent substation improvements. The commuter rail systems have 213 equivalent substations that would require improvement.

A discussion of the proposed improvements in each of the major rail areas follows:

- BOSTON

The rapid rail system has 24 equivalent substation improvements. 8 substations in "bad" condition are scheduled to be replaced the end of 1984. 4 equivalent substations were proposed to receive a level 1 or level 2 modernization. An additional 20 equivalent substations were proposed for a level 7 refurbishment during the 10-year period from 1985 to 1994. The proposed improvements include the purchase of spare parts,

TABLE 4.6

POWER DISTRIBUTION - SUBSTATION IMPROVEMENTS (Each)

Major Rail Areas	Rapid Rail				Light Rail				Commuter Rail			
	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	4	-	20	24	-	-	-	None	-	-	-	None
New York	264	-	-	264				NA	85	83	-	168
Northern NJ	7	1	14	22	5	-	-	5	5	-	-	5
Southern NJ	-	-	-	None				NA				NA
Philadelphia	8	-	-	8	4	-	-	4	15	-	-	15
Pittsburgh				NA	4	-	-	4				NA
Washington, DC	1	-	68	69				NA				NA
Chicago	11	-	36	47				NA	18	7	-	25
Cleveland	-	-	-	None	-	-	-	None				NA
Atlanta	-	-	-	None				NA				NA
New Orleans				NA	-	-	-	None				NA
San Francisco	-	-	-	None	-	-	-	None				NA
San Diego				NA	-	-	-	None				NA
TOTAL	295	1	138	434	13	-	-	13	123	90	-	213

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

replacement of spare breakers, station battery replacement and PCB transformer replacement at the older substation locations. Also included is the replacement of substation getaway cables, addition of new disconnect switches and replacement of deteriorated duct banks, as required. An addition of more disconnects/isolation switches and feeder cables from the substation locations to obtain better sectionalization within the power distribution system was also proposed.

The power distribution system for the light rail system is provided by the rapid rail system. As a result, improvements are included in the rapid rail figures.

- NEW YORK

The rapid rail system has 264 equivalent substations that would require modernization. All of substations in "poor" condition range in age from 48 to 73 years and are all scheduled for a level 1 modernization; however, the proposed improvements have not yet been funded. The modernization program includes the replacement of all antiquated equipment in accordance with a previously developed replacement schedule.

The commuter rail systems have 168 proposed equivalent substation improvements. Of these 168 improvements, 85 are level 1 modernizations and 83 are level 3 rehabilitations. Improvements include conversion of 3 AC substations from 25 cycle to 60 cycle, replacement of DC breakers, battery sets and motor generators. Also proposed as part of the modernization project are 24 new substations.

- NORTHERN NEW JERSEY

The rapid rail system has 22 equivalent substation improvements and 14 of these would require refurbishment and 1 rehabilitation. In addition, 7 new substations are proposed.

The light rail system has 5 proposed equivalent substation improvements, all of which are level 2 modernizations.

The commuter rail system has no proposed improvements since improvement programs have already been scheduled and funded. However, 5 new substations are proposed.

- SOUTHERN NEW JERSEY

The rapid rail system's substations are all in "good" condition. Therefore, no additional improvements should be required before 1994.

- PHILADELPHIA

The rapid rail system has substations in "poor" and "fair" condition that would require modernization or rehabilitation; however, all but 8 have already been funded.

The light rail system has 4 substations that are each about 64 years old. Therefore, a level 2 modernization has been proposed for these 4 substations. This modernization program includes the replacement of AC primary switchgear, transformers, rectifiers, DC switchgear and feeder cables.

The commuter rail system has 15 equivalent substation improvements and a level 2 modernization program was proposed. These substations are all 50 to 60 years old and most of the older equipment should be replaced.

- PITTSBURGH

The light rail system has 4 substations that would have to be modernized. An improvement program is already in progress and specific requirements for the new equipments for these old substations has been developed.

- WASHINGTON, DC

The rapid rail system has 68 equivalent substations which require a level 7 refurbishment in the next 10 years. In addition, 1 new substation is proposed.

- CHICAGO

The rapid rail system has 47 proposed equivalent substation improvements, including 11 that require modernization and 36 refurbishment. Of the 11 proposed for modernization, 6 substations would receive new tie breakers and 4 would be new.

The commuter rail system has 7 equivalent substations that would require rehabilitation. In addition, 18 substation locations would receive modernization of the transfer trip signaling system. An additional 3 substations have already been scheduled for modernization.

- CLEVELAND

The rapid rail system has all substations presently in "good" condition and no capital improvements should be required.

The light rail system has all substations either in "good" or "excellent" condition; therefore no improvements should be required.

- ATLANTA

The rapid rail system has all substations in "excellent" condition; therefore no capital improvements should be required before 1994.

- NEW ORLEANS

The light rail system has 1 substation for which a level 4 modernization would be required. However, because it is presently owned by New Orleans Public Service Incorporated (NOPSI), therefore no publicly financed capital improvement program was proposed.

- SAN FRANCISCO

The rapid rail system has all substations in "good" condition; therefore no improvement projects were identified.

The light rail system has all substations either in "good" or "excellent" condition; therefore no improvement projects were identified for these substations.

- SAN DIEGO

The light rail system has all substations presently in "excellent" condition; therefore no improvement projects were identified.

o Power Distribution - Overhead Wire Improvements

The proposed overhead wire improvements which would be required to leave all overhead wire in "good" or better condition at the end of the 10-year period are provided in Table 4.7. It should be noted that these numbers represent the number of equivalent miles of overhead wire being improved. Subsystems other than catenary were converted to equivalent miles of overhead wire being improved. Also, these projects sometimes affect the same segment of overhead wire more than once. For example, one improvement project could rehabilitate a segment of overhead wire, and a second system-wide refurbishment might affect the same segment of overhead wire. As a result, the number of equivalent miles of overhead wire shown in Table 4.7 may be greater than the actual miles of overhead wire in the system.

The rapid rail systems have 8 miles of overhead wire that would require improvement and all of this wire is located in Boston. The light rail systems have 184 equivalent miles that would require improvement and this is primarily in Boston and Philadelphia. The commuter rail systems have 1,236 equivalent miles of overhead wire that would require improvement and most of this is located in New York, Philadelphia, and Chicago.

A discussion of the proposed improvements in each of the major rail areas follows:

- BOSTON

  The rapid rail system has 8 miles of overhead wire requiring a level 7 refurbishment.

TABLE 4.7

POWER DISTRIBUTION - OVERHEAD WIRE IMPROVEMENTS (Miles)

	Rapid Rail				Light Rail				Commuter Rail			
Major Rail Areas	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	-	-	8	8	75	-	38	113				NA
New York				NA				NA	251	-	-	251
Northern NJ				NA	13	-	-	13	26	-	-	26
Southern NJ				NA				NA				NA
Philadelphia				NA	46	-	-	46	489	-	-	489
Pittsburgh				NA	12	-	-	12				NA
Washington, DC				NA				NA				NA
Chicago	-	-	-	None				NA	-	100	370	470
Cleveland	-	-	-	None	-	-	-	None				NA
Atlanta				NA				NA				NA
New Orleans				NA	-	-	-	None				NA
San Francisco				NA	-	-	-	None				NA
San Diego				NA	-	-	-	None				NA
TOTAL	-	-	8	8	146	-	38	184	766	100	370	1236

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

The light rail system has 113 equivalent miles of overhead wire improvements. 75 equivalent miles of overhead wire should receive a level 1 or 2 modernization. A level 6 or level 7 refurbishment, is proposed for the remaining 38 equivalent miles. These projects include improvements to the catenary, as well as to poles, foundations and underground wire.

- NEW YORK

The commuter rail system has 251 equivalent miles of overhead wire that would require modernization. This improvement includes the complete replacement of the outdated triangular twin messenger system with the more reliable single messenger, 3-wire support system with constant tension.

- NORTHERN NEW JERSEY

The light rail system requires 13 equivalent miles of overhead wire improvements. A level 2 modernization of 4 miles includes modernizing the existing catenary system, including the wiring, poles, and foundations. An additional 9 equivalent miles of overhead wire was proposed for a level 1 modernization to replace sectionalizing switches.

The commuter rail system requires no additional improvements to those already funded; however, 26 new miles of overhead wire are proposed.

- PHILADELPHIA

The light rail system has 26 equivalent miles of overhead wire that would require a level 4 modernization, and 20 equivalent miles that would require a level 1 modernization. These projects are part of an ongoing program to replace all overhead wire. It includes modernizing the wire to the same extent being completed throughout the SEPTA power distribution system and associated program.

The commuter rail system has 489 equivalent miles of overhead wire that would require modernization during the period from 1985 to 1994. This modernization is also part of the ongoing program to replace all overhead wire. The proposed projects include 17 miles of new overhead wire as well as replacement of catenary, static wire and sectionalizing switches.

- PITTSBURGH

The light rail system has 12 equivalent miles of overhead wire that would require modernization. The proposed improvements will bring the wire up to the same capability as the remaining overhead wire, which is presently in "excellent" condition.

- CHICAGO

The rapid rail system has overhead wire that is in "good" overall condition. Therefore, no improvements were proposed.

The commuter rail systems have 470 equivalent miles of overhead wire refurbishments. Although some of the necessary improvements have already been completed, the refurbishment of 370 equivalent miles and the rehabilitation of 100 equivalent miles would be required to bring all of the overhead wire to "good" condition.

- CLEVELAND

The rapid rail system has overhead wire in "good" overall condition. Therefore, no improvements were proposed.

The light rail system has overhead wire in "good" overall condition. Therefore, no improvements were proposed.

- NEW ORLEANS

The light rail system contains overhead wire in "fair" condition and would require a level 4 modernization. However, this overhead wire is also owned by the New Orleans Public Service Incorporated and therefore no specific projects were proposed.

- SAN FRANCISCO

The light rail system has overhead wire which is all in "good" condition. Therefore, no specific improvement projects were proposed.

- SAN DIEGO

The light rail system has overhead wire which is all in "good" or "excellent" condition. As a result, no improvement projects were proposed.

o Power Distribution - Third Rail Improvements

The proposed third rail improvements which would be required to leave all third rail in "good" or better condition at the end of the 10-year period are provided in Table 4.8. It should be noted that these numbers represent the number of equivalent miles of third rail being improved.

TABLE 4.8

POWER DISTRIBUTION - THIRD RAIL IMPROVEMENTS (Miles)

Major Rail Areas	Rapid Rail				Light Rail				Commuter Rail			
	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	136	-	-	136				NA				NA
New York	355	-	-	355				NA	262	265	-	527
Northern NJ	29	-	-	29				NA				NA
Southern NJ	-	-	30	30				NA				NA
Philadelphia	31	11	-	42	22	-	-	22				NA
Pittsburgh				NA				NA				NA
Washington, DC	-	19	-	19				NA				NA
Chicago	102	43	218	363				NA				NA
Cleveland				NA				NA				NA
Atlanta	-	-	-	None				NA				NA
New Orleans				NA				NA				NA
San Francisco	-	-	-	None				NA				NA
San Diego				NA				NA				NA
TOTAL	653	73	248	974	22	-	-	22	262	265	-	527

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

Subsystems other than third rail were converted to equivalent miles of third rail being improved. Also, these projects sometimes affect the same segment of third rail more than once. For example, one improvement project could rehabilitate a segment of third rail, and a second system-wide refurbishment might affect the same segment of third rail. As a result, the number of equivalent miles of third rail shown in Table 4.8 may be greater than the actual miles of third rail in the system.

The rapid rail systems have 974 equivalent miles of third rail improvements and 36 percent of this is in New York and 37 percent is in Chicago. The light rail systems have only 22 equivalent miles of third rail that would require improvement and all of this is located in Philadelphia. The commuter rail systems require 527 equivalent miles of third rail improvements and all of this is located in New York.

A discussion of the proposed improvements in each of the major rail areas follows:

- BOSTON

  The rapid rail system requires 136 equivalent miles of third rail modernization. These improvements include the replacement of existing third rail with new 150 lb/yd composite contact rail (aluminum clad steel). An addition of more disconnects/isolation switches and feeders from substation locations to obtain better sectionalizing within the power distribution system has also been proposed.

- NEW YORK

  The rapid rail system has approximately 355 equivalent miles of third rail that should receive a level 2 modernization. These improvements include the upgrading of the negative and positive bonding at various locations and replacing of all power related hardware and equipment on sections of the line, where necessary. All third rail in "fair" condition will not require additional capital improvements since the funding is already included in the ongoing program.

  The commuter rail system has 527 equivalent miles of third rail improvements. 262 equivalent miles of third rail would require a level 1 modernization. A level 3 rehabilitation is proposed for 265 equivalent miles of third rail. The proposed improvements include the replacement of existing third rail, installation of additional electrically operated sectionalizing switches along the third rail, and the replacement of coverboard, where required.

- NORTHERN NEW JERSEY

  The rapid rail system has third rail in "fair" condition, and most of the required improvements of this third rail have already been funded and the material has been acquired. However, a level 1 modernization is proposed to replace sectionalizing switches on 29 equivalent miles of this third rail.

- SOUTHERN NEW JERSEY

  The rapid rail system has 30 miles of third rail which would require a level 7 refurbishment during the next 10 years to replace cover boards.

- PHILADELPHIA

  The rapid rail system requires 42 equivalent miles of third rail improvements. Of this, 11 miles would require a level 5 rehabilitation. This improvement includes the upgrading of the third rail, replacement of traction power sectionalizing switches and breakers at selected locations, replacement of positive traction feeder cables, and other similar types of improvements. Another proposed modernization project would replace sectionalizing switches on 31 equivalent miles of third rail.

The light rail system has 22 equivalent miles of third rail which would require a level 2 modernization. This improvement includes the replacement of traction power feeder cables on selected routes, as well as replacement of the third rail.

- WASHINGTON, DC

The rapid rail system has all third rail in "good" condition overall. However, 19 equivalent miles are proposed for level 5 rehabilitation for feeder cables.

- CHICAGO

The rapid rail system requires 363 equivalent miles of third rail improvements, including 102 equivalent miles of modernization, 43 equivalent miles of rehabilitation, and 218 equivalent miles of refurbishment. These improvements include the replacement of the existing 70 lb/yd contact rail and subway positive and negative contact and running rail paralleling cables. They also include the addition of more sectionalizing switches systemwide and the upgrading of deteriorating wood enclosures with fiberglass enclosures. Also proposed was the rehabilitation of existing contact rail heaters and the insulation of rail heaters at inclines of service yards, passenger station getaways and yard areas, including heater controls, as appropriate.

- ATLANTA

The rapid rail system has all third rail in "excellent" condition; therefore no improvements were proposed.

- SAN FRANCISCO

The rapid rail system has all third rail in "good" condition. No improvements were proposed for this third rail.

o System-Wide Control Improvements

The proposed improvements to the system-wide control system element for the rail transit systems to leave all in "good condition at the end of the 10-year period are provided in Table 4.9. The rapid rail systems have 11 system-wide control system elements that would require improvement during the period from 1985 to 1994; this includes 7 systems that would require modernization, 2 that require rehabilitation and 2 that would require refurbishment. The light rail systems have 6 system-wide control system elements that would require improvement including 2 that would require modernization, 2 refurbishment, and 2 rehabilitation. The commuter rail systems have 11 system-wide control system elements that would require improvement, including 7 that would require modernization, 3 that would require rehabilitation and 1 that would require refurbishment. The system-wide control element includes a train control subsystem, a communications subsystem and a supervisory and control subsystem. Each of these subsystems contain various components that are comprised of units/equipment that performs that system-wide control

TABLE 4.9

SYSTEM-WIDE CONTROL IMPROVEMENTS (Each)

Major Rail Areas	Rapid Rail				Light Rail				Commuter Rail			
	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	1	-	-	1	1	-	-	1	1	-	-	1
New York	2	-	-	2				NA	2	-	-	2
Northern NJ	-	1	-	1	-	1	-	1	-	1	-	1
Southern NJ	1	-	-	1				NA				NA
Philadelphia	1	-	-	1	-	1	-	1	-	1	-	1
Pittsburgh				NA	1	-	-	1	-	-	1	1
Washington, DC	-	-	1	1				NA				NA
Chicago	1	-	-	1				NA	4	1	-	5
Cleveland	-	-	1	1	-	-	1	1				NA
Atlanta	-	-	1	1				NA				NA
New Orleans				NA	-	-	-	None				NA
San Francisco	-	1	-	1	-	-	1	1				NA
San Diego				NA	-	-	-	None				NA
TOTAL	6	2	3	11	2	2	2	6	7	3	1	11

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

functions. These individual subsystems were evaluated separately and improvements required for each subsystem, unit, or equipment were then determined. The level of improvement indicated in Table 4.7 is a summary of the improvements required for each of these individual pieces of equipment.

A discussion of the proposed system-wide control improvements in each of the designated rail areas follows, with some emphasis on specific types of equipment and subsystems.

- BOSTON

The proposed improvements to the system-wide control element for the rapid rail system include the installation of a completely new wayside signal system along the Blue Line, replacing electro-pneumatic switches at train stop mechanisms with all electric switches, adding new track switches where required, and providing an automatic vehicle identification monitor to allow for the automatic alignment of routes at interlockings as well as to provide track occupancy information to central control.

Proposed improvements also include the installation of a new communication cable on the Blue Line and controls for radio communications that will facilitate the use of PAX instruments along the Blue Line. The proposed improvements also include the replacement of portable radios, the upgrading of 12 of the 30 public address systems installed on the Red Line and the installation of 2 or 4 preamplifiers per station, mixers, cabinets and handsets at various station locations for use by maintenance personnel.

The proposed improvements for the light rail system include installation of a completely new wayside signal system on the subway portion of the Green Line, upgrading of the existing 25 Hz single rail track circuits to 60 Hz double rail track circuits, as well as the installation of state-of-the-art signaling systems. Also, some type of protection should be provided, whether it be in the form of standard automatic trip stops or newer induction operated stops. The improvements should also include the installation of an automatic vehicle identification system to facilitate route control and dispatching. The wayside signal on the Highland Branch from Kenmore to Riverside should be renovated and updated. This improvement should include conversion to 60 Hz double rail track circuits, respacing of signals and replacement of deteriorated cables. A train location system should also be installed. A communication cable should be installed on the entire Green and Mattapan Shuttle Lines (approximately 25 miles). This cable would be used for public address, telephone communications, and a new PAX telephone system. The PAX emergency telephone system would be installed on the entire light rail system. The installation of this telephone system will involve the replacement of "dual function" telephones at stations and in tunnels between stations. It was also proposed to install a public address system at stations on the Mattapan Shuttle Line.

A general system-wide improvement program was proposed for the commuter rail system, which would encompass a majority of existing train control and communication equipment. The present supervisory and control equipment is neither extensive nor in need of major improvements. The primary concern is with restoring the communication and train control subsystems to a condition of "good repair". Worn and obsolete items should be replaced with equivalent or improved components or materials. In some instances, improvement to the original and/or present capability should be considered. The proposed improvement programs included the consolidation of the control and monitoring of those portions of the system having CTC capability at one central location and the installation of additional control sidings to allow for increased two-way traffic flow with minimum delay.

- NEW YORK

The rapid rail system would require the modernization of 2 system-wide control elements. The proposed improvements include the installation of a new system to remotely monitor and control traction power subsystems on the

IND Line. The central portion of this system would be installed in the power control center in Manhattan. Approximately 70 percent of the fire emergency call boxes also would need to be replaced; this could be as many as 7,000 units. The maintenance telephone system also would need to be improved, including the telephones and equipment rooms and towers. There would also be a requirement to replace the telephone switching equipment used for operations and administrative purposes. Proposed additional improvements included the modernization of the signal system, signal relay code system, antenna cable, telephone cable, maintenance-of-way communications and other communication subsystems. The signaling improvements proposed include the installation of new wayside signal equipment. The type of track circuits to be used would be those which can be utilized if the system is connected to cab signaling at some time in the future. Additional proposed improvements included rebuilding the Tottenville interlocking and remote control for the St. George interlocking control room and providing control and monitoring provisions for the new/improved traction power generation facilities on the SIRTOA Transit System.

The commuter rail system also has 2 system-wide control system elements that would both require modernization. The proposed improvements include installing wayside cab signaling equipment with overspeed protection on all branches in the main commuting area, which are not already equipped or scheduled to be equipped with this capability. Reverse signaling equipment should also be installed on selected tracks in those areas as well as in other branches in the main commuting area which are already equipped with cab signaling equipment. Some sections of track would also require improved signaling that are outside of the main commuting area. The old electro-pneumatic interlocking equipment should be replaced by electrical systems which are capable of being remotely controlled; this would also require new wiring. A central control facility in the area of Jamaica Station is also proposed; this facility should be capable of controlling all interlocking equipment in the main commuting area. It was also proposed that some of the old deteriorated wayside equipment cases be replaced with new cases; there could be as many as 100 cases which require replacement. It was also to be proposed that new software be developed for the new computerized data logging system in the power department. This software would add some additional information management functions to the system. It was also proposed that a separate channel for radio communication between the power director's office and the field sources be installed. Other improvements include the installation and replacement of obsolete radio-based stations and radio control units.

- NORTHERN NEW JERSEY

The rapid rail system-wide control system element would require rehabilitation. The proposed improvements include the standardization of tunnel signal units, rehabilitating the signals at the Henderson Yard and Hudson Interlocking, neutralizing the relay status recording system, rehabilitating the signal cable messenger support system, providing protection for the signal system, replacing track circuits at Hoboken, replacing public announcing systems, rehabilitating antennas and base stations, replacing track circuit equipment, replacing the power supervisory control subsystem, expanding and replacing the CCTV system, rebuilding the train to wayside communication system, and other types of equipment rehabilitation.

The light rail system-wide control subsystem would require rehabilitation. The proposed improvements include the installation of a CCTV system to provide for the security of passengers and train operators. Additional proposed improvements included the replacement of all of the wiring associated with the signaling system. Also the insulated joints, impedance bonds and their connections to the rails should be replaced on a "as needed" basis. It was also proposed that 10 additional radio units be provided for the cars and 4 additional portable radio units be obtained.

The commuter rail system-wide control subsystem element would need to be rehabilitated. Proposed improvements include the purchase of equipment for the supervisory control system, the purchase and installation of signals and communications equipments, construction of the signal, communications and power cable, modernization and expansion of the telephone system, making major improvements to the wiring and cabling throughout the system, refurbishing intrusion alarm systems, replacing existing open wire pull lines for signals and communications with buried multi-conductor cable, refurbishing the present radio equipment as needed, and refurbishing the internal telephone system equipment with specific attention to selected systems. Selected portions of the wayside signal system were also proposed for modernization as part of the long term improvement program. Additional proposed improvements included the purchase of various types of major equipments and subsystems.

- SOUTHERN NEW JERSEY

The rapid rail system-wide control subsystem element should be modernized. Proposed improvements include the upgrading of the monitoring and control capabilities of the central tower facility, revising and/or renewing the train protection provisions associated with the Market Street and Ferry Avenue Interlockings, replacing the internal telephone system, revising and/or renewing the CCTV system, and replacing existing cabling with improved smokeless cables.

- PHILADELPHIA

The rapid rail system-wide control subsystem element would require modernization. While the system-wide control element, in general, is considered to be in "good" condition, much of the train protection equipment is 50 years old, obsolete and possesses low MTBF values. Therefore, the proposed improvements included the rehabilitation or replacement of selected subsystems, modernizing the existing wayside signal systems along both rapid rail lines, replacing much of the obsolete equipment.

The light rail system-wide control system element is in generally "good" condition, but much of the equipment is more than 70 years old and obsolete. The proposed improvements include rehabilitating or replacing selected individual items of equipment, replacing selected equipments on the RAD, providing additional maintenance of the radio system, replacing the existing trolley phone system on the subway/surface line with a new radio system, and modernizing the existing wayside signal systems along all light rail lines.

The commuter rail system-wide control system element would require rehabilitation. Recommended improvements include modernizing the existing wayside signal system along the various lines, revising and modernizing the existing wayside signaling system along the rail lines which are being electrified, installing wayside cab signal provisions on a selected basis so that the amount of cab signaled territory is enlarged and made continuous, and continued consolidation of interlocking/CTC function at a central location. The communications subsystem also would need modernization including improved voice communications throughout the entire system, especially PA capabilities at stations and wayside/maintenance phones.

- PITTSBURGH

The light rail system-wide control system element would require modernization. Proposed improvements include the installation of new wayside signals and associated track circuits, installing trip stops in association with all the new signals, providing for CCTV at designated stations/stops, installing communication cables in traction power substations, providing the necessary modifications/additions to a central control facility, providing for automatic route selection including vehicle-borne selectable route ID and wayside readers associated with the track switch control logic, installing new radios on the recently acquired LRV cars, and installing a new internal telephone system.

The commuter rail system-wide control system element would require refurbishment. Proposed improvements include the installation of new signals on the 3.1 mile section of track closest to Pittsburgh, installing additional train control signals on the siding track in the vicinity of Braddock, and integrating the proposed new electric switch, at the station siding at Versailles, with the controls at the local signal tower. This last improvement would also require additional track circuits and interconnections with the existing B&O and P&LE track circuits and wayside signals.

- WASHINGTON, DC

The rapid rail system-wide control system element is presently in "good" condition, but it would require improvement during the next 10 years. Proposed improvements include replacing the failing CCTV cameras with new light units, upgrading the capabilities of the cable carrier system, incorporating portions of the overall OCC renewal plans as they relate to system-wide controls, performing rehabilitation of the system-wide control element equipment, installing new internal telephone systems because the existing system is now at capacity, replacing portions of the existing radio equipment, and providing and adding other types of equipment, as required.

- CHICAGO

The rapid rail system-wide control system element would require modernization during the next 10 years. Proposed improvements include the replacement of worn cabling associated with the wayside signals, replacement of ABS signaling with cab signaling of the type now in service throughout the system, replacing the punch tape-type dispatching machines with new units, completely rehabilitating the portions of traction power supervisory and monitoring equipment concerned with data transmission to and from the tower substations, and consolidating and centralizing the control of selected interlockings in order to facilitate operations and reduce labor costs.

The commuter rail system includes 5 system-wide control system elements, 4 of which would require modernization and 1 which would require rehabilitation during the next 10 years. The proposed improvements include providing temporary signaling, respacing and replacing old track circuits, installing CTC equipment, rehabilitating interlockings, installing new multi-pair communication cable, replacing the old telephone system, upgrading the aerial cable used for CCTV, replacing TV monitors, and providing additional equipment, as needed.

- CLEVELAND

The system-wide control system elements on both the light rail and rapid rail systems would require refurbishment during the next 10 years. Proposed improvements include rehabilitating the rapid rail communications, and converting the light rail line between CUT and Shaker Square from wayside to cab signals.

- ATLANTA

The rapid rail system-wide control system element would require refurbishment during the next 10 years. Proposed improvements include the replacement of vehicle-borne ATO and ATP, wayside ATO and ATP, CCTV, cable carriers, communication equipment, and supervision equipment.

- SAN FRANCISCO

The rapid rail system-wide control system element would require rehabilitation during the next 10 years. Proposed improvements include the replacement of the ATO units on the existing A Cars with the new type being developed and provided for the new C Cars, expanding and modernizing the existing train control/supervision capabilities, improving and/or modifying the existing train detection circuits in order to provide shorter headways than those allowed by the present SORS system, and rehabilitating the system-wide control element equipment on an "as needed" basis.

The light rail system-wide control system element would require refurbishment during the next 10 years. Proposed improvements include the modification of the telephone, PA, and central radio systems, and making additional improvements to the system-wide control related features that are associated with the reconstruction of a Forest Hills Station. Additional proposed improvements include selectively refurbishing the telephone equipment, modernizing the monitoring provisions related to fare collection, rehabilitating the CCTV cameras utilized for monitoring passenger safety and security at the stations, and conducting general refurbishment activities associated with the system-wide control components.

- SAN DIEGO

Automatic train operation is not utilized on the light rail system. Each train is completely manually controlled by a single on-board operator. However, an automatic permissive block signaling system with AC track circuits, insulated joints, and impedance bond is utilized on the sections of the track outside of the city. The light rail system maintains unmanned traction power substations and there is no remote monitoring or control of these substations. Facilities monitoring is limited to security provisions for the fare collection equipment. As a result, the only improvements which would be required are related to radio equipment, which consists of one base station at central control, several repeater sites, and numerous hand-held units used by operation and maintenance personnel as well as the train operators. Since the equipment is new and the light rail system is being expanded, additional improvements, other than those necessary for normal preventive maintenance, were not identified or proposed.

o Station Improvements

The proposed improvements to the stations for the rail transit systems which would be required to leave all in "good" or better condition at the end of the 10-year period are provided in Table 4.10. The rapid rail systems have nearly 804 stations and station stops or 20 million square feet of station area that would require improvement. Sixty-one percent of the stations which would require improvement are in the New York area, 17 percent in the Chicago area, and 5 percent in the Washington, D.C. area. However, based on station area, the percentages change to 66 percent in New York, 7 percent in Washington, D.C. and 7 percent in Chicago. The light rail systems have approximately 785,000 square feet of station area that would require improvement, or 295 stations and station stops. Of these 295 stations and station stops, 24 percent are in the Boston area, 28 percent in the Philadelphia area and 34 percent are in San Francisco. However, 45 percent of the station area which would require improvement is in Boston, 21 percent is in Philadelphia, and 32 percent is in San Francisco. The commuter rail systems have approximately 4 million square feet of station area that would require improvement or 803 stations and station stops. Approximately 27 percent of these stations are in New York, 18 percent in Philadelphia and 25 percent in the Chicago area. In terms of physical dimensions, 39 percent of the station area which would require improvement is in New

York, 20 percent is in Northern New Jersey, and 23 percent is in the Chicago area.

A discussion of the proposed improvements in each of the major rail areas follows:

- BOSTON

The rapid rail system has 48 stations, not including station stops. Approximately 33 stations or 682,000 square feet would require improvement. The 50,000 square feet in "poor" condition would require modernization, 149,000 would require rehabilitation, and 483,000 would require refurbishment. Station improvements include modernization to inhibit saltwater intrusion, installing new entrances to provide access to the financial district stations, additional improvements to effect the interface between rapid rail, commuter and long distance rail services, providing new sound insulation and power supplies, installing better lighting and fare collection equipment, upgrading some interior finishes, replacing roofing membranes and providing other station amenities where required. In some situations, new construction has provided the shafts for the elevators but the elevators have not yet been purchased and installed.

The light rail system has 96

TABLE 4.10

STATION IMPROVEMENTS (Thousands of Square Feet)

Major Rail Areas	Rapid Rail				Light Rail				Commuter Rail			
	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	50	149	483	682	4	-	345	349	-	31	193	224
New York	1395	8294	3289	12978				NA	646	168	778	1592
Northern NJ	12	190	149	351	-	-	-	None	294	280	253	827
Southern NJ	20	-	148	168				NA				NA
Philadelphia	518	37	185	740	74	11	77	162	121	233	56	410
Pittsburgh				NA	19	-	-	19	-	-	24	24
Washington, DC	-	-	1444	1444				NA	-	12	6	18
Chicago	94	453	921	1468				NA	396	116	430	942
Cleveland	80	77	22	179	-	-	2	2				NA
Atlanta	-	-	874	874				NA				NA
New Orleans				NA				NA				NA
San Francisco	6	-	751	757	-	-	253	253	34	7	10	51
San Diego				NA	-	-	-	None				NA
TOTAL	2175	9200	8266	19641	97	11	677	785	1491	847	1750	4088

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

stations and station stops, approximately 71 of which would require improvement. This equates to 4,000 square feet which would require modernization and 345,000 which would require refurbishment. Most of the stations have recently been modernized and only a nominal amount of rehabilitation or refurbishment is proposed to most of the stations. These efforts would primarily address deterioration due to wear and vandalism.

The commuter rail system has 67 stations and station stops that would require improvement. The 67 stations contain 224,000 square feet that would require improvement including 31,000 that would require rehabilitation and 193,000 that would require refurbishment. Improvements have been proposed to graphics, lighting, landscaping, paved areas, shelters, platforms, roofs/canopies, pedestrian track crossings, and parking areas.

- NEW YORK

The rapid rail systems have a total of 487 stations, all of which would require some type of improvement. These stations contain nearly 13 million square feet of station area. As indicated in Table 4.10, nearly 1.4 million square feet (62 stations) would require modernization, 8.3 million (298 stations) would require rehabilitation, and 3.3 million (127 stations) would require refurbishment. The proposed improvements vary considerably, depending upon the actual physical condition of each station. Where applicable, these improvements include modifications to reduce water intrusion, spalling, leaking and leaching; modifications to horizontal and vertical circulation systems, including stairs, ramps, escalators, elevators, and hand rails; increasing the lighting in subway stations to eliminating the darker areas, and improving the mechanical/electrical equipment, where necessary.

The commuter rail system has 250 stations, and there are 216 stations and station stops that would require improvement. These 216 stations and station stops consist of nearly 1.6 million square feet of area and of this, 646,000 would require modernization, 168,000 would require rehabilitation, and 778,000 would require refurbishment. The proposed improvements vary, depending upon the actual physical condition of each station. Where necessary, improvements were proposed to the horizontal and vertical circulation systems, fare collection equipment, security systems, interior/exterior finishes, the structures, and mechanical/electrical equipments.

- NORTHERN NEW JERSEY

The rapid rail system has a total of 13 stations. Improvements have been proposed for all 13 stations including 1 station that should be modernized, 9 that should be rehabilitated and 3 that should be refurbished. The area corresponding to these 13 station improvements include 12,000 square feet that should be modernized, 190,000 that should be rehabilitated, and 149,000 that should be refurbished. The proposed improvements include installing standpipe systems in the subway stations, improving the ventilation, providing emergency egress, replacing turnstiles and installing emergency power where necessary.

The light rail system has 11 stations and all of these were in either "fair" or "excellent" condition. Modernization and rehabilitation projects have already been funded for these light rail stations, and no additional project improvements have been proposed.

The commuter rail system has 167 stations, with 128 which would require improvement. Of these, 52 stations would require modernization, 40 rehabilitation and 36 refurbishment. These 128 stations consist of approximately 800,000 square feet of station area. The proposed improvements vary, depending upon the actual physical condition of each station, and include modifications to the horizontal and vertical circulation systems, fare collection equipment improvement, cleaning and painting the interior/exterior finishes, making improvements to the structures, and replacing mechanical/electrical equipment wherever necessary.

- SOUTHERN NEW JERSEY

The rapid rail system has 13 stations and 11 of these 13 stations would require some type of improvement during the next 10 years. One station would require modernization and 10 would require refurbishment. The area associated with these 11 stations is approximately 168,000 square feet. The proposed improvements include improving the station graphics, modifying the fare collection equipment, painting the station interiors and exteriors, improving the subway ventilation for smoke control, installing communications and public address systems, improving security measures, rehabilitating the station roofs and concrete platforms, waterproofing the platforms surfaces and rehabilitation of the downtown subway stations.

- PHILADELPHIA

The rapid rail system has 53 stations including 18 in "excellent" condition which will not require any improvement during the next 10 years. However, 35 stations would require improvement, including 25 that would require modernization, 3 would require rehabilitation and 7 which would require refurbishment. The 35 stations which would require improvement contain nearly 740,000 square feet of station area. Since many of the Market Street subway stations are currently being modernized and the improvement programs have identified the items requiring modification, the proposed improvements are related to this already established program. These improvements include modifications to the horizontal and vertical circulation systems, fare collection equipment, interior/exterior finishes, structure, and mechanical/electrical equipment, wherever necessary.

The light rail system includes 163 stations and station stops. Of these, there are 83 which would require improvement including 11 that would require modernization, 9 rehabilitation, and 63 refurbishment. These 83 stations and station stops contain approximately 162,000 square feet of station area. Since there is an ongoing rehabilitation program for the stations, proposed improvements were similar to those contained in this established program. In addition, some lighting, security, and graphics improvements were proposed.

The commuter rail system has 177 stations and station stops. There are 148 stations and station stops which would require some type of improvement during the next 10 years. These improvements include 24 stations and station stops that would require modernization, 99 that would require rehabilitation and 25 that would require refurbishment. These 148 stations and station stops include nearly 410,000 square feet of station area. The proposed improvements include modifications to horizontal and vertical circulation systems, interior/exterior finishes, structures, and mechanical/electrical equipment, where necessary. The proposed improvements are also in agreement with the SEPTA station improvement program.

- PITTSBURGH

The light rail system has no stations but does have 35 station stops which would require modernization. These 35 station stops consist of approximately 19,000 square feet of station area. The proposed improvements include new platforms and installing non-slip finishes on the steps leading to the platforms.

The commuter rail system has 5 stations and 4 of these were in "good" condition and 1 in "excellent" condition. The 4 stations in "good" condition would require some type of refurbishment during the next 10 years. These 4 stations contain approximately 24,000 square feet of station area. The proposed improvements include the provision of waterproof wearing surfaces on the platforms, additional parking, and other types of minor improvements.

- WASHINGTON, DC

The rapid rail system has 48 stations; 44 of these stations were in "good" condition and 4 in "excellent" condition. The 44 stations in "good" condition would require some type of refurbishment during the next 10 years. These stations are relatively large and contain more than 1.4 million square feet of station area. The proposed improvements include weatherproofing the canopies at the street level, improving the illumination in the parking lots, improving the station lighting, modifying the fare collection equipment, waterproofing the escalator machine rooms, eliminating the leakage in the control station tunnel, and increasing the parking capacity, where necessary.

The commuter rail system has 31 stations and there are approximately 13 stations and station stops that would require modernization, rehabilitation, or refurbishment during the next 10 years. These 13 stations and station stops contain nearly 18,000 square feet of station area. The proposed improvements include providing new high level platforms and additional parking, proper siding for passenger loadings, and other similar types of improvements.

- CHICAGO

The rapid rail system has 144 stations, and there are a total of 136 stations and station stops that would require some type of improvement during the period from 1985 to 1994. The proposed improvements include 9 stations and station stops that would require modernization, 44 rehabilitation, and 83 refurbishment. The 136 stations contain approximately 1.4 million square feet of station area. The proposed improvements include improving the station graphics and amenities, modifying the fare collection equipment, improving station interior and exterior architectural finishes, improving the heating ventilation system, improving communications and public address systems, improving security measures, rehabilitating station roofs, rehabilitating the concrete platforms, and waterproofing the platforms surfaces, wherever appropriate.

The commuter rail system has 241 stations. The total number of stations and station stops which would require improvement is 203, including 70 that would require modernization, 33 rehabilitation, and 100 refurbishment. These 203 stations and station stops consist of approximately 942,000 square feet of station area that requires improvement. The proposed improvements include improving the station graphics and lighting, rehabilitating the horizontal surfaces and station roofs, making repairs to the structures and mechanical/electrical equipment where necessary and pertinent.

- CLEVELAND

The rapid rail system has 18 stations with 17 stations and station stops which would require improvement. Four of these would have modernization, 10 rehabilitation and 3 refurbishment. These 17 stations and station stops consist of 179,000 square feet of station area that requires improvement. The proposed improvements include rehabilitation of horizontal and vertical circulation systems, fare collection equipment, interior/ exterior finishes, structures, and mechanical/electrical equipment where appropriate. Some improvements to the station amenities were also proposed.

The light rail system has 1 station, and 24 station stops. These station stops were in relatively "good" condition and would require only minor repairs. Therefore, only 5 station refurbishments were proposed.

- ATLANTA

The rapid rail system has 20 stations, and all of these are in "good" or "excellent" condition. It was estimated that 14 of these stations would require refurbishment during the next 10 years. These 14 stations were all relatively large and consist of approximately 874,000 square feet of station area. The proposed improvements include correcting the water intrusion problems, making minor improvements to the horizontal and vertical circulation systems, fare collection equipment, interior/exterior finishes, structures, and mechanical/ electrical equipment, where appropriate.

- NEW ORLEANS

The light rail system has no

stations and no capital improvements were proposed for the station stops.

- SAN FRANCISCO

The rapid rail system has 34 stations, mostly in "good" condition. Fourteen of these stations would require refurbishment during the period from 1985 to 1994. These 14 stations contain approximately 757,000 square feet of station area. The proposed improvements included making safety improvements to the edge of the platforms, providing additional parking space, providing additional fare collection equipment, and making minor improvement to the horizontal and vertical circulation systems, interior/exterior finishes, structures, and mechanical/ electrical equipment, where necessary.

- SAN DIEGO

The 18 stations and station stops in San Diego were all in "excellent" condition and no improvements were proposed.

o Structures and Facilities -Bridge Improvements

The proposed improvements to the bridges for the rail transit systems to bring all bridges to "good" or better condition by the end of the 10-year period are provided in Tables 4.11 and 4.12. These bridges have been separated into 2 major categories; elevated railways and all bridges except elevated railways. This separation was necessary due to the differences in the inspection and measurement procedures and in establishing cost estimates. The rapid rail systems have approximately 1.8 million square feet (excluding elevated railways) and 1.1 million lineal feet of elevated railways. Some type of modernization, rehabilitation or refurbishment would be required on 1.5 million square feet of bridges and less than 1 million lineal feet of elevated railways. With the exception of elevated railways, 28 percent of the area which would require improvement is in the New York area, 17 percent in the Boston area, 19 percent in the Chicago area, and 20 percent in the Cleveland area. However, 52 percent of the elevated railways which would require improvement are in the Chicago area and 38 percent in the New York area.

The light rail systems have 380,000 square feet of bridges (excluding elevated railways) and 6,000 lineal feet of elevated railways. Approximately 265,000 square feet of bridges and all 6,000 lineal feet of elevated railways would require some type of improvement during the next 10 years. Most of the elevated railways which would require improvement are in the Philadelphia area. Thirty-four percent of the area, in terms of square footage, of the other types of bridges is in Philadelphia, 28 percent in Boston, and 29 percent in Cleveland.

The commuter rail systems have approximately 9.1 million square feet of bridges and approximately 8.9 million square feet would require some type of improvement during the 10-year period. In addition, approximately 69,000 lineal feet of elevated railways out of a total of 93,000 lineal feet would require improvements. Approximately 80 percent of the elevated railways which would require improvements are in New York with most of the rest in either Northern New Jersey

TABLE 4.11

STRUCTURES AND FACILITIES - BRIDGE IMPROVEMENTS (EXCLUDING ELEVATED RAILWAYS)

(Thousands of Square Feet)

Major Rail Areas	Rapid Rail				Light Rail				Commuter Rail			
	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	-	49	210	259	9	62	3	74	1	312	93	406
New York	18	203	211	432				NA	15	2118	1110	3243
Northern NJ	5	66	-	71	-	2	-	2	-	1303	173	1476
Southern NJ	-	53	16	69				NA				NA
Philadelphia	-	14	-	14	3	60	27	90	25	962	62	1049
Pittsburgh				NA	-	1	20	21	-	6	30	36
Washington, DC	-	8	76	84				NA				NA
Chicago	-	256	27	283				NA	29	1332	1309	2670
Cleveland	-	278	29	307	-	78	-	78				NA
Atlanta	-	-	3	3				NA				NA
New Orleans				NA	-	-	-	None				NA
San Francisco	-	-	-	None	-	-	-	None				NA
San Diego				NA	-	-	-	None				NA
TOTAL	23	927	572	1522	12	203	50	265	70	6033	2777	8880

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

TABLE 4.12

STRUCTURES AND FACILITIES - BRIDGE IMPROVEMENTS (ELEVATED RAILWAYS)

(Thousands of Lineal Feet)

Major Rail Areas	Rapid Rail				Light Rail				Commuter Rail			
	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	-	24	2	26	-	1	-	1	1	1	-	2
New York	-	340	-	340				NA	-	39	16	55
Northern NJ	-	2	-	2	-	-	-	None	-	5	-	5
Southern NJ	-	1	5	6	-	-	-	None				NA
Philadelphia	-	52	-	52	-	4	1	5	-	6	1	7
Pittsburgh				NA	-	-	-	None				NA
Washington, DC	-	-	-	None				NA				NA
Chicago	-	469	6	475				NA	-	-	-	None
Cleveland	-	3	-	3	-	-	-	None				NA
Atlanta	-	-	-	None				NA				NA
New Orleans				NA	-	-	-	None				NA
San Francisco	-	-	-	None	-	-	-	None				NA
San Diego				NA	-	-	-	None				NA
TOTAL	-	891	13	904	-	5	1	6	1	51	17	69

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

or Philadelphia. Of the other types of bridges which would require improvement, approximately 37 percent of the bridge area is in New York, 17 percent in Northern New Jersey, 12 percent in Philadelphia, and 30 percent in the Chicago area.

A discussion of the proposed improvements in each of the major rail areas follows:

- BOSTON

  The rapid rail system has 259,000 square feet of bridges (excluding elevated railways) which would require improvement including 49,000 square feet that would require rehabilitation and 210,000 square feet that would require refurbishment. In addition, 24,000 lineal feet of elevated railways would be rehabilitated and 2,000 lineal feet would be refurbished. The improvements generally involve removing and replacing deteriorated concrete; sandblasting and painting steel, while replacing severely corroded parts; repairing or replacing wood, steel or concrete decks.

  The light rail system has 74,000 square feet of bridges and 1,000 lineal feet of elevated railways that would require improvement. These improvements include the rehabilitation of approximately 1,000 lineal feet of elevated railway and 9,000 square feet of other types of bridges that would require modernization, 62,000 square feet that would require rehabilitation and 3,000 square feet that would require refurbishment.

  The commuter rail system has 406,000 square feet of bridges and 2,000 lineal feet of elevated railways that would require improvement. These bridges include 1,000 lineal feet of elevated railways that would require modernization and 1,000 lineal feet that would require rehabilitation. Of the other types of bridges, approximately 1,000 square feet would require modernization, 312,000 square feet would require rehabilitation and 93,000 square feet would require refurbishment.

- NEW YORK

  The rapid rail system has 432,000 square feet of bridges and 340,000 lineal feet of elevated railways that would require improvement. The proposed improvements include 340,000 lineal feet of elevated railway that would require rehabilitation and 18,000 square feet of other types of bridges that would require modernization, 203,000 square feet that would require rehabilitation and 211,000 square feet that would require refurbishment.

  The commuter rail system has approximately 3.2 million square feet of bridges and 55,000 lineal feet of elevated railways that would require improvement. These improvements include 39,000 lineal feet of elevated railway that would require rehabilitation and 16,000 lineal feet that would require refurbishment. Of the other types of bridges, approximately 15,000 square feet would require modernization, 2,118,000 square feet would require rehabilitation and 1,111,000 square feet would require refurbishment.

- NORTHERN NEW JERSEY

  The rapid rail system has 71,000

square feet of bridges and 2,000 lineal feet of elevated railways that would require improvement, including approximately 2,000 lineal feet of elevated railway and 5,000 square feet of other types of bridges that would require modernization, and 66,000 square feet that would require rehabilitation.

The light rail system has 1 bridge that would require rehabilitation and this bridges consists of approximately 2,000 square feet of area.

The commuter rail system has 1.5 million square feet of bridges that would require improvement and approximately 5,000 lineal feet of elevated railway that would require rehabilitation. The bridge improvements include 1.3 million square feet that would require rehabilitation and 173,000 square feet that would require refurbishment.

- SOUTHERN NEW JERSEY

The rapid rail system has 69,000 square feet of bridges and 6,000 lineal feet of elevated railways that would require improvement. These improvements include the rehabilitation of 1,000 lineal feet of elevated railway and the refurbishment of 5,000 lineal feet that would require refurbishment. Of the other types of bridges, approximately 53,000 square feet would require rehabilitation and 16,000 square feet would require refurbishment.

- PHILADELPHIA

The rapid rail system has 52,000 lineal feet of elevated railway and 14,000 square feet of other types of bridges that would require rehabilitation.

The light rail system has 90,000 square feet of bridges that would require improvement, and 4,000 lineal feet of elevated railway that would require rehabilitation and 1,000 lineal feet that would require refurbishment. Of the 90,000 square feet, 3,000 square feet of other types of bridges would require modernization, 60,000 square feet would require rehabilitation and 27,000 square feet would require refurbishment.

The commuter rail system has over 1 million square feet of bridges that would require some type of improvement, including 25,000 square feet that would require modernization, 962,000 square feet that would require rehabilitation, and 62,000 square feet that would require refurbishment. In addition, 6,000 lineal feet of elevated railway would require rehabilitation and 1,000 lineal feet would require refurbishment.

- PITTSBURGH

The light rail system has 21,000 square feet of bridges that would require improvement including 1,000 square feet that would require rehabilitation and 20,000 square feet that would require refurbishment. The light rail system has no elevated railways that would require improvement.

The commuter rail system has 36,000 square feet of bridges that would require improvement including 6,000 square feet that would require rehabilitation and 30,000 square feet that would require refurbishment. There are no elevated railways that would require improvement.

- WASHINGTON, DC

The rapid rail system has 133,000 square feet of bridges and 84,000 square feet of these would require rehabilitation or refurbishment. None of the elevated railways would require improvement.

- CHICAGO

The rapid rail system has 283,000 square feet of bridges and all of these would require rehabilitation or refurbishment during the next 10 years. In addition, 469,000 lineal feet of elevated railways would require rehabilitation and 6,000 lineal feet would require refurbishment.

The commuter rail systems have 2.7 million square feet of bridges that would require improvement, including 29,000 square feet that would require modernization, 1.3 million square feet that would require rehabilitation and 1.3 million square feet that would require refurbishment. There are no proposed improvements to the elevated railways.

- CLEVELAND

The rapid rail system has 307,000 square feet of bridges all of which would require some type of improvement, and 3,000 lineal feet of elevated railway that would require rehabilitation. About 278,000 square feet of the bridges would require rehabilitation and 29,000 square feet would require refurbishment.

The light rail system has 78,000 square feet of bridges and all of these would require rehabilitation during the next 10 years. There are no elevated railways that would require improvement.

- ATLANTA

The rapid rail system has 24,000 square feet of bridges and 3,000 square feet would require refurbishment during the next 10 years.

- NEW ORLEANS

The light rail system has no bridges.

- SAN FRANCISCO

The rapid rail system has 206,000 square feet of bridges and 123,000 lineal feet of elevated railways and all of these were in "excellent" condition. As a result, no improvements are proposed during the next 10 years.

The light rail system has no bridges and no elevated railways.

- SAN DIEGO

The light rail system has 113,000 square feet of bridges and all of these are in "good" or "excellent" condition. As a result, no improvements are required during the next 10 years.

o Structures and Facilities -Tunnel Improvements

The proposed tunnel improvements for the rail transit systems to bring all tunels to "good" or better condition by the end of the 10-year period are provided in Table 4.13. The rapid rail systems have approximately 291 miles of tunnel and of this total, 258 miles would require some type of modernization, rehabilitation or refurbishment. The New York area has over 50 percent of the length of tunnel which would require improvement, the next greatest length being in

TABLE 4.13

STRUCTURES AND FACILITIES - TUNNEL IMPROVEMENTS (Thousands of Lineal Feet)

Major Rail Areas	Rapid Rail				Light Rail				Commuter Rail			
	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	-	62	-	62	1	17	12	30	-	-	2	2
New York	-	625	62	687				NA	-	42	-	42
Northern NJ	-	14	62	76	-	-	-	None	-	9	-	9
Southern NJ	14	13	1	28				NA				NA
Philadelphia	-	88	-	88	-	-	-	None	-	-	11	11
Pittsburgh				NA	-	-	-	None	-	-	-	None
Washington, DC	-	-	90	90				NA				NA
Chicago	-	-	111	111				NA	-	-	1	1
Cleveland	1	1	4	6	-	-	-	None				NA
Atlanta	-	-	27	27				NA				NA
New Orleans				NA	-	-	-	None				NA
San Francisco	-	-	187	187	-	3	19	22				NA
San Diego				NA	-	-	-	None				NA
TOTAL	15	803	544	1362	1	20	31	52	-	51	14	65

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

San Francisco (14 percent) and Chicago (8 percent).

The light rail systems have approximately 11 miles of tunnel and of this total, almost 10 miles would require some type of modernization, rehabilitation or refurbishment. Almost 58 percent of the tunnel which would require improvement is located in Boston with the remaining 42 percent in San Francisco.

The commuter rail systems have almost 13 miles of tunnel and most of it would require some type of improvement; 65 percent of the length of tunnel is located in New York with most of the rest either in Northern New Jersey or Philadelphia.

A discussion of the proposed improvements in each of the major rail areas follows:

- BOSTON

The rapid rail system has 62,000 lineal feet of tunnel and all of it would require rehabilitation, with particular emphasis on improving the condition of the liners.

The light rail system has 30,000 lineal feet of tunnel and 1,000 lineal feet which would require modernization, 17,000 lineal feet rehabilitation and 12,000 lineal feet refurbishment.

The commuter rail system has

approximately 2,000 lineal feet of tunnel; it is in "good" condition but would require refurbishment during the next 10 years.

- NEW YORK

The rapid rail systems have 687,000 lineal feet of tunnel and all of it would require either rehabilitation or refurbishment during the next 10 years.

The commuter rail system has 43,000 lineal feet of tunnel and 42,000 lineal feet would require rehabilitation during the next 10 years.

- NORTHERN NEW JERSEY

The rapid rail system has 76,000 lineal feet of tunnel and all of it would require either rehabilitation or refurbishment during the next 10 years.

The light rail system has 7,000 lineal feet of tunnel that is in "fair" condition; this rehabilitation has already been funded and no additional improvements have been proposed.

The commuter rail system has 9,000 lineal feet of tunnel that is in "poor" condition; this tunnel would all require rehabilitation during the next 10 years.

- SOUTHERN NEW JERSEY

The rapid rail system has 28,000 lineal feet of tunnel and all of it would require modernization, rehabilitation or refurbishment during the next 10 years.

- PHILADELPHIA

The rapid rail system has 88,000 lineal feet of tunnel that is in "fair" condition, but it would require rehabilitation during the next 10 years.

The commuter rail system has 13,000 lineal feet of tunnel that is in "fair" condition and 11,000 lineal feet would requre refurbishment during the next 10 years.

- WASHINGTON, DC

The rapid rail system has 90,000 lineal feet of tunnel that is in "good" condition, but it would require refurbishment during the next 10 years.

- CHICAGO

The rapid rail system has 111,000 lineal feet of tunnel that is in "good" condition and would require refurbishment during the next 10 years.

The commuter rail system has 1,000 lineal feet of tunnel that is in "good" condition and would require refurbishment during the next 10 years.

- CLEVELAND

The rapid rail system has 1,000 lineal feet of tunnel that is in "poor" condition that would require rehabilitation and 4,000 lineal feet that is in "good" condition that would require refurbishment during the next 10 years.

- ATLANTA

The rapid rail system has 28,000 lineal feet of tunnel and 27,000 lineal feet would require refurbishment during the next 10 years.

- SAN FRANCISCO

The rapid rail system has 362,000 lineal feet of tunnel and 187,000 lineal feet would require refurbishment during the next 10 years.

The commuter rail system has 22,000 lineal feet of tunnel and all of it would require either rehabilitation or refurbishment during the next 10 years.

o Maintenance Facility Building Improvements

The proposed improvements to the maintenance facility buildings for the rail transit systems to bring all maintenance buildings to "good" or better condition by the end of the 10-year period are provided in Table 4.14. The rapid rail systems have 102 major maintenance facility buildings and 71 of these would require modernization, rehabilitation or refurbishment during the next 10 years. Approximately 45 percent of the maintenance facility buildings which would require improvement are located in the New York area, 15 percent in the Chicago area and the remainder are located in Boston, Northern New Jersey, Southern New Jersey, Philadelphia, Cleveland, Washington and Atlanta. The 71 buildings contain 3,500,000 square feet of area and approximately 2.0 million square feet would require modernization, 520,000 square feet would require rehabilitation and

TABLE 4.14

MAINTENANCE FACILITY BUILDING IMPROVEMENTS

(Thousands of Square Feet)

Major Rail Areas	Rapid Rail				Light Rail				Commuter Rail			
	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	2	53	352	407	38	-	153	191	166	-	-	166
New York	1520	-	32	1552				NA	1291	-	-	1291
Northern NJ	125	-	60	185	-	-	-	None	166	-	6	172
Southern NJ	-	-	106	106				NA				NA
Philadelphia	-	195	-	195	133	-	45	178	150	43	-	193
Pittsburgh				NA	-	-	-	None				NA
Washington, DC	186	-	151	337				NA				NA
Chicago	143	272	41	456				NA	314	-	423	737
Cleveland	35	-	1	36	-	-	-	None				NA
Atlanta	-	-	226	226				NA				NA
New Orleans				NA	-	103	-	103				NA
San Francisco	-	-	-	None	-	-	230	230				NA
San Diego				NA	-	-	-	None				NA
TOTAL	2011	520	969	3500	171	103	428	702	2087	43	429	2559

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

almost 1 million square feet would require refurbishment. The light rail systems contain 16 major maintenance facility buildings and 13 of these would require some type of improvement during the next 10 years. About 38 percent of these buildings are located in Boston, 31 percent in Philadelphia and the remainder in San Francisco and New Orleans. These 13 buildings contain 702,000 square feet of area and 171,000 square feet would require modernization, 103,000 square feet would require rehabilitation and 428,000 square feet would require refurbishment. The commuter rail system has 35 major maintenance facility buildings and 31 of these buildings would require some type of improvement during the next 10 years; including 27 that would require modernization, 1 that would require rehabilitation and 3 that would require refurbishment. These 31 buildings contain approximately 2.5 million square feet of area.

A discussion of the proposed improvement in each of the major rail areas follows. (Relatively detailed maintenance facility building improvements have been developed for each building and are contained in the individual transit system condition reports; they have not been duplicated in the following descriptions of the improvements.)

- BOSTON

  The rapid rail system has 5 maintenance facility buildings and all of these would require some type of improvement. The transportation building is in "bad" condition and contains approximately 2,000 square feet of area; it would require modernization during the next 10 years. One building of 53,000 square feet would require rehabilitation and 3 buildings of 352,00 square feet would require refurbishment. The proposed improvements include making provisions for new blowout facilities; ventilation, exterior switches for overhead door operations; disconnect switches in the carwash areas; additional tracks for inspecting and servicing the vehicles; new truck hoists and other types of equipment; larger storage areas; emergency generators; spaces for carpentry and sheet metal shops; special types of equipment such as bridge cranes, electrical outlets, metal storage racks, etc. Specific improvements have been proposed for each maintenance facility building.

  The light rail system has 5 buildings that would require either modernization or refurbishment. The carhouse is in "fair" condition and contains 38,000 square feet that would require modernization. The other carhouses and transportation building contain 153,000 square feet that would require refurbishment. The proposed improvements include providing sump pumps and sump pits in wheel-truing and floor-jack areas; a blowout collection system; new electrical power service to the air strippers; new lighting throughout the shops; new storage areas for operations; various types of new equipments such as jib cranes, floor hoists, lighting indicators, air curtains at the exterior overhead doors, etc. Specific improvements were proposed for each of the maintenance facility buildings depending upon its capability and present condition.

  The commuter rail system has 1 maintenance facility building that is in "bad" condition and consists of 166,000 square feet that would require modernization. It was proposed that this old facility be completely removed and replaced with an entirely new maintenance facility.

- NEW YORK

The rapid rail system has 47 maintenance facility buildings that would require improvement, but improvement of 15 of these buildings has already been funded. The remaining 32 buildings include approximately 1.5 million square feet of area, most of which would require modernization. Specific improvements for these maintenance facility buildings have already been developed and are part of the approved maintenance program.

The commuter rail system has 17 maintenance facility buildings and 14 of these would require improvement during this 10-year period. These buildings contain approximately 1.3 million square feet of area that would require modernization. Specific improvements were developed for each of the maintenance facilities.

- NORTHERN NEW JERSEY

The rapid rail system has 4 maintenance facility buildings and 3 of these are in "poor" condition and one is in "bad" condition; all 4 would require improvement during this period from 1985 to 1994. These 4 buildings include 125,000 square feet that would require modernization and 60,000 square feet that would require refurbishment.

The light rail system has 1 maintenance facility building that is in "good" condition and no improvements were proposed during the 10-year period.

The commuter rail system has 5 maintenance facility buildings and 1 of these was in "good" condition and 4 in "poor" condition. Three of these buildings would require modernization and 1 would require refurbishment during the period from 1985 to 1994. These improvements include 166,000 square feet that would require modernization and 6,000 square feet that would require refurbishment.

- SOUTHERN NEW JERSEY

The rapid rail system has 3 maintenance facility buildings that are in "good" condition and 2 of these buildings would require refurbishment during the period from 1985 to 1994. The 2 buildings contain approximately 106,000 square feet.

- PHILADELPHIA

The rapid rail system has 4 maintenance facility buildings that contain approximately 195,000 square feet that would all require rehabilitation during the next 10 years.

The light rail system has 4 maintenance facility buildings and 3 of these would require modernization and 1 refurbishment during the next 10 years. The 3 buildings which would require modernization contain approximately 133,000 square feet and the building which would require refurbishment contains about 45,000 square feet of area.

The commuter rail system has 2 maintenance facility buildings and 1 of these is in "fair" condition and the other in "bad" condition. Both of these buildings would require improvements during the next 10 years. The 1 building which would require modernization contains approximately 150,000 square feet and the building which would require rehabilitation contains 43,000 square feet of area.

- PITTSBURGH

The light rail system has 1 brand new maintenance facility that is in "excellent" condition and no improvements have been proposed.

- WASHINGTON, DC

The rapid rail system has 3 maintenance facility buildings and 2 of these are in "good" condition and 1 in "fair" condition. The building in "fair" condition would require modernization during the next 10 years and the other 2 buildings would require refurbishment. The area associated with the buildings proposed for modernization is approximately 186,000 square feet and the other 2 buildings have about 151,000 square feet of area proposed for refurbishment.

- CHICAGO

The rapid rail system has 11 maintenance facility buildings and 1 of these is in "good" condition, 7 are in "fair" condition and 3 in "poor" condition. All 11 buildings would require improvement during the next 10 years, including 5 proposed for modernization, 5 rehabilitation and 1 refurbishment. The 5 buildings proposed for modernization include 143,000 square feet of area; the 5 proposed for rehabilitation contain 272,000 square feet and the building for refurbishment contains about 41,000 square feet of area.

The commuter rail systems have 10 maintenance facility buildings and all of these would require improvement during the next 10 years. Eight of these buildings for modernization and 2 for refurbishment. The 8 buildings proposed for modernization contain 314,000 square feet of area and the 2 buildings for refurbishment contain 423,000 square feet of area.

- CLEVELAND

The rapid rail system has 9 maintenance facility buildings and 3 of these are in "excellent" condition, 1 in "good" condition and 5 in "fair" condition. The 5 buildings in "fair" condition would require improvement, including 4 proposed for modernization and 1 for refurbishment. The 4 buildings proposed for modernization contain approximately 35,000 square feet of area and the small building proposed for refurbishment contains only 1,000 square feet of area.

The light rail system utilizes the same maintenance facilities as the rapid rail system and therefore no additional improvements have been proposed.

- ATLANTA

The rapid rail system has 2 maintenance facility buildings that are both in "good" condition. However, these 2 buildings would require refurbishment during the next 10 years and include approximately 226,000 square feet of area.

- NEW ORLEANS

  The light rail system has 2 maintenance facility buildings and both are in "fair" condition. These 2 buildings would both require rehabilitation and contain approximately 103,000 square feet of area.

- SAN FRANCISCO

  The rapid rail system has 14 maintenance facility buildings and 2 of these are in "excellent" condition and 12 in "good" condition. As a result, no improvement have been proposed to these maintenance facility buildings during the next 10 years.

  The light rail system has 2 maintenance facility buildings which were both in "good" condition. These 2 buildings would both require refurbishment during the next 10 years and contain approximately 230,000 square feet of area.

- SAN DIEGO

  The light rail system has 1 maintenance facility building that is in "excellent" condition and therefore no improvements were proposed for the next 10 years.

o Maintenance/Storage Yard Improvements

The proposed improvements to the maintenance/storage yards to ensure that all yards are in "good" or better condition at the end of the 10-year period are provided in Table 4.15. The rapid rail systems have 59 maintenance/storage yards. Forty-eight of these yards would require improvement during the next 10 years and most of these improvements are required in the New York and the Chicago areas. The light rail systems have 12 maintenance/storage yards. Ten of these maintenance/storage yards would require improvement and most of these yards are located in the Boston and Philadelphia areas. These yards contain approximately 2.38 million square feet of area. The commuter rail systems contain 61 maintenance/storage yards. Of these 61 yards, 57 would require improvement during the next 10 years with most of these being located in the Chicago area. The area associated with these maintenance facilities is approximately 2.3 million square feet.

A discussion of the proposed improvements in each of the major rail areas follows. (Relatively detailed maintenance yard improvements have been developed for each yard and are contained in the individual transit system condition reports; they have not been duplicated in the following descriptions of the improvements.)

- BOSTON

  The rapid rail system has 4 maintenance/storage yards and all are in "fair" condition. These 4 yards would all require improvement during the next 10 years, with 1 proposed for modernization and 3 for refurbishment. The yard proposed for modernization contains approximately 688,000 square feet of area and the 3 yards proposed for refurbishment contains approximately 1.35 million square feet of area.

TABLE 4.15

MAINTENANCE/STORAGE YARD IMPROVEMENTS

(Thousands of Square Feet)

Major Rail Areas	Rapid Rail				Light Rail				Commuter Rail			
	MO	RH	RF	T	MO	RH	RF	T	MO	RH	RF	T
Boston	688	-	1350	2038	-	109	619	728	218	-	-	218
New York	17119	-	-	17119				NA	3599	-	-	3599
Northern NJ	653	-	-	653	-	-	64	64	87	2684	392	3163
Southern NJ	-	-	871	871				NA				NA
Philadelphia	964	274	-	1238	237	-	318	555	1787	-	-	1787
Pittsburgh				NA	-	-	-	None				NA
Washington, DC	-	-	1168	1168				NA				NA
Chicago	1760	340	738	2838				NA	7694	3116	3807	14617
Cleveland	-	188	479	667	-	-	-	None				NA
Atlanta	-	-	-	None				NA				NA
New Orleans				NA				NA				NA
San Francisco	-	-	-	None	-	-	348	348				NA
San Diego				NA	-	-	684	684				NA
TOTAL	21184	802	4606	26592	237	109	2033	2379	13385	5800	4199	23384

Legend: MO - Modernization RH - Rehabilitation RF - Refurbishment T - Total

NA - Not Applicable

The light rail system has 5 maintenance/storage yards and 1 of these was in "excellent" condition, 1 in "good" condition, and 3 in "fair" condition. Four of these yards would require improvement during the next 10 years with 1 proposed for rehabilitation and 3 for refurbishment. The yard proposed for rehabilitation contains about 109,000 square feet of area and the 3 yards proposed for refurbishment contains 619,000 square feet of area.

The commuter rail system has 1 maintenance/storage yard which is in "bad" condition and would require modernization. This yard contains approximately 218,000 square feet of area.

- NEW YORK

The rapid rail system has 25 maintenance/storage yards and these were all in "poor" condition. However, the funding for 5 of the improvements has already been provided and therefore only the remaining 20 yards would require modernization. These 20 yards contain approximately 17 million square feet of area.

The commuter rail system has 13 maintenance/storage yards and 1 of these was in "excellent" condition and the other 12 in "poor" condition. Nine of the maintenance/storage yards would require modernization during this 10-year period (the other 3 in "poor" condition have already been funded for improvement). These 9 yards contain approximately 3.6 million square feet of area.

- NORTHERN NEW JERSEY

The rapid rail system has 3 maintenance/storage yards and all are in "fair" condition and would require modernization during the next 10 years. These 3 yards contain approximately 653,000 square feet of area.

The light rail system has 1 maintenance/storage yard that is in "good" condition and would only require refurbishment during the next 10 years. This yard contains approximately 64,000 square feet of area.

The commuter rail systems have 14 maintenance/storage yards that are all in "fair" condition and would require some type of improvement during the next 10 years. One of these yards would require modernization, 11 rehabilitation and 2 refurbishment. The yard which would require modernization contains approximately 87,000 square feet of area; the 11 yards proposed for rehabilitation contain nearly 2.7 million square feet of area; and the 2 yards proposed for refurbishment contain approximately 392,000 square feet of area.

- SOUTHERN NEW JERSEY

The rapid rail system has 1 maintenance/storage yard that is in "good" condition. This yard contains approximately 871,000 square feet that would require refurbishment during the next 10 years.

- PHILADELPHIA

The rapid rail system has 3 maintenance/storage yards that are all in "poor" condition and would require some type of improvement during the next 10 years. Two of these yards would require modernization and contain approximately 964,000 square feet of area; the other yard would require rehabilitation and contains approximately 274,000 square feet of area.

The light rail system has 3 maintenance/storage yards and 2 of these are in "bad" condition and 1 in "good" condition. All 3 of these yards would require some type of improvement, including 2 that would require modernization and 1 refurbishment during the next 10 years. The 2 yards which would require modernization contain approximately 237,000 square feet of area and the yard which would require refurbishment contains 318,000 square feet of area.

The commuter rail system has 3 maintenance/storage yards and 2 of these were in "bad" condition and 1 in "poor" condition. All 3 yards would require some type of modernization and contain approximately 1.8 million square feet of area.

- PITTSBURGH

The light rail system has 1 maintenance/storage yard that was recently completed and is in "excellent" condition; therefore no improvement projects have been identified for this yard.

- WASHINGTON, DC

The rapid rail system has 3

maintenance/storage yards that are in "good" condition; but all 3 yards would require some type of refurbishment during the next 10 years. These 3 yards contain approximately 1.2 million square feet of area.

- CHICAGO

The rapid rail system has 12 maintenance/storage yards and 11 of these would require some type of improvement during the next 10 years. Six of these yards would require modernization and consist of about 1.8 million square feet of area. One yard would require rehabilitation and contains about 340,000 square feet of area. The other 4 yards would require refurbishment and contain about 738,000 square feet of area.

The commuter rail systems have 30 maintenance/storage yards and 3 of these were in "good" condition, 15 in "fair" condition, 11 in "poor" condition and 1 in "bad" condition. All 30 of these yards would require some type of improvement during the next 10 years, with 13 proposed for modernization, 7 for rehabilitation and the other 10 for refurbishment. The 13 yards proposed for modernization contain nearly 7.7 million square feet of area; the 7 yards proposed for rehabilitation contain about 3.1 million square feet of area and the yards proposed for refurbishment contain 3.8 million square feet of area.

- CLEVELAND

The rapid rail system has 4 maintenance/storage yards and 2 of these are in "good" condition and 2 in "poor" condition. Three of these would require improvement during the next 10 years with 2 yards proposed for rehabilitation and 1 yard for refurbishment. The 2 yards proposed for rehabilitation contain about 188,000 square feet of area and the 1 yard for refurbishment contains about 479,000 square feet of area.

The light rail system utilizes the same yards as the rapid rail system and therefore no additional improvements are required.

- ATLANTA

The rapid rail system has 1 maintenance/storage yard which was recently completed and is in "excellent" condition. As a result, no additional improvements should be required during the next 10 years.

- SAN FRANCISCO

The rapid rail system has 3 maintenance/storage yards that were all in "good" condition and no capital improvements should be required during the next 10 years.

The light rail system has 1 maintenance/storage yard that is in "good" condition and would require some type of refurbishment during the next 10 years. This yard contains approximately 348,000 square feet of area.

- SAN DIEGO

The light rail system has 1 maintenance/storage yard that is in "good" condition. This yard would require some type of refurbishment during the next 10 years and contains approximately 684,000 square feet of area.

5.0 CAPITAL COST ESTIMATES AND EVALUATION OF FUNDING REQUIREMENTS

The capital cost estimates were initially developed to indicate the costs of upgrading and modernizing all segments of the rail transit systems to be consistent with current standards of safety, reliability, efficiency and aesthetics. The cost effectiveness of proposed improvements was then evaluated to determine estimates of the benefits associated with different funding levels.

Two different methods of estimating cost-effectiveness were developed. Both methods required dividing the different types of transit systems into identifiable and logical segments/branches. Passenger miles, as a measure of passenger utilization, was estimated for each of these segments/branches. One cost-effectiveness method used the ratio of passenger miles to capital costs as a means to compare the relative effectiveness of improvements on the branches/segments. The other method used unit benefit modifiers developed by LTI to estimate operating cost savings and passenger benefits (in dollars) attributable to proposed capital improvements on each segment/branch. The sum of operating cost savings and passenger benefits divided by the cost of improvements for each system element gives a benefit/cost ratio for an improvement project on a segment/branch. Summarizing the ratios for all the improvements on a segment/branch gives an initial estimate of the cost-effectiveness of all the proposed improvements on each branch/segment. Analysis of these two sets of ratios suggests the prioritization of proposed improvements on the different segments/branches for each type of transit system within respective geographical areas. The results of this analysis are provided in Sections 5.5 and 5.7. The resulting change in condition of each system element for various capital expenditure levels is provided in Section 5.6 and provides additional insight into the impact of alternative levels of funding with respect to the benefits obtained.

5.1 GENERAL PROCEDURE FOR DEVELOPING CAPITAL COST ESTIMATES

The general procedure for developing the capital cost estimates was explained in Chapter 2. The magnitude of the type of improvements proposed for the major system elements and subsystems was explained in Chapter 4.

In developing a standardized approach to cost estimation, the initial requirement was to develop specific definitions for each system element and major subsystem for each proposed level of improvement. The general definitions for each level of improvement were provided in Table 4.2 and an example of the more specific definitions is provided in Table 5.1. Similar types of specific definitions were developed for each type of rail car; power distribution substations, overhead wire and third rail; system-wide controls; each type of rail station, structures and facilities, and maintenance facility buildings and storage yards. As indicated in Table 5.1, each level of improvement involves possible changes to all of the major components and subsystems of that system element. The level 1 (modernization) includes extensive replacement or addition of new track and way components which will provide a better level of service than originally provided. The percentages change with each level of improvement: starting with 70 to 100 percent for level 1 and ending with 0 to 10 percent for level 7. Also, the type of material used in making the improvement may change with each category of improvement in accordance with the following basic definitions:

- o Modernization is a level of rail system improvement whereby original equipment or materials are replaced with proven new equipment or materials to achieve higher levels of performance or productivity. Modernization includes the

TABLE 5.1

COST ESTIMATE DEFINITIONS

TRACK

Component	Level of Improvement 1	2	3	4	5	6	7
Rail	Replace 70% to 100% with heavier rail.	Replace 40% to 70% with heavier rail.	Replace 70% to 100% with rail of same weight.	Replace 20% to 40% with heavier rail.	Replace 40% to 70% with rail of same weight.	Replace 10% to 40% with rail of same weight.	Replace less than 10% with rail of same weight.
Rail Joints	Continuous shop welded rail.	Continuous shop welded rail.	Continuous shop welded rail.	Continuous shop welded rail.	Continuous shop welded rail.	Continuous shop welded rail.	Replace missing joint bolts and tighten bolts.
Rail Fastening and Anchor Systems	Install spring clip type fastener and anchor system.	Install spring clip type fastener system on new rail.	Install new tie plates and spikes.	Install spring clip type fastener system on new rail.	Install new tie plates and spikes.	Install new tie plates and spikes.	Replace broken rail anchors.
Ties/Cross Ties	Install new concrete ties.	Install new concrete ties with replaced rail.	Replace 85% of ties with new ties of same type.	Install new concrete ties with replaced rail.	Replace 55% of ties with new ties of same type.	Replace 25% of ties with new ties of same type.	Replace defective ties (15%).
Ballast and Sub-ballast	Replace with crushed stone ballast.	Replace with crushed stone ballast.	Clean fouled crushed stone ballast and add new crushed stone ballast, as req.	Replace with crushed stone ballast.	Clean fouled crushed stone ballast and add new crushed stone ballast, as req.	Clean fouled crushed stone ballast and add new crushed stone ballast, as req.	Clean fouled ballast.
Special Trackwork and Machinery	Install no. 20 type electrically controlled switches.	Install no. 20 type electrically controlled switches.	Replace all worn switch points and frogs with new components.	Install no. 20 type electrically controlled switches.	Replace all worn switch points and frogs with new components.	Replace all worn switch points and frogs with new components.	
Track Alignment, Gauge and Surface	Line and surface all new track.	Line and surface all new track.	Line and surface all new track.	Line and surface all new track.	Line and surface all new track.	Line and surface all new track.	o 80% to 100% rail grinding. o Line and surface track.
Roadway/Embankment	o Widen and stabilize embankment. o Replace sump pumps. o Add fencing.	o Widen and stabilize embankment. o Replace sump pumps. o Add fencing.	o Stabilize eroded embankment areas o Clean ditches. o Replace damaged fence components.	o Widen and stabilize embankment. o Replace sump pumps. o Add fencing.	o Stabilize eroded embankment areas o Clean ditches. o Replace damaged fence components.	o Stabilize eroded embankment areas o Clean ditches. o Replace damaged fence components.	o Remove dense vegetation along roadbed. o Clean ditches.

replacement of facilities and equipment which are functionally or economically obsolete with new components, subsystems, and/or entire units.

- o Rehabilitation is a lesser level of rail system improvement than modernization whereby worn or weakened materials, components and subsystems are replaced with new parts having basically the same design or function as the original equipment. Rehabilitation includes the renovation of existing facilities or equipment, as necessary, to achieve original levels of service, safety, capacity or reliability.

- o Refurbishment is a still lesser level of rail system improvement whereby existing equipment or facilities are restored to adequate levels of performance without the necessity for major replacement of parts or components. Refurbishment should result in the capacity to sustain existing system performance.

It can also be assumed that some track components may be replaced to support a dominant component, in this case, the rail. When 70 to 100 percent of the rail is replaced with heavier rail, only the replaced rail would probably receive new rail fastening and anchor systems and be shop welded before installation; the ballast and subballast would probably also be replaced under the new rail. However, it was necessary to consider some improvements that were not dominated by the primary component; that is, roadway and embankment improvements may be necessary for the entire rail section and not just the sections that are receiving new rail. These types of modifications to the general definitions were considered for each specific project.

The next requirement was to develop unit cost estimates for each component included in the cost estimate, whenever feasible and practical. The unit costs were then multiplied by the quantities for each improvement to obtain a cost estimate for each component and then a total cost estimate for each subsystem in the improvement project. These total cost estimates included costs of the material, installation, contractor overhead and profit, but not the contingencies, regional cost differences or inflation. These additional cost items were included in the development of the final project cost estimate and project staging. These cost data were then entered on the Project Formulation Sheet for computer analysis, as explained in Section 4.1.

The cost estimates developed for each system element were based on the evaluation of the components, subsystems, and other factors associated with the particular system element. Some of the more important aspects of this development are discussed in the following paragraphs:

- o Track

  The components of the track system that were contained in each cost estimate included the rail, rail joints, rail fastening and anchor systems, ties/crossties, ballast and subballast, special trackwork and machinery, track alignment, gauge and surface, and roadway and embankment. Unit costs were developed for each item for each level of improvement and specific project. The quantity of the items to be improved was then multiplied by the unit cost to obtain a project cost estimate.

- o Vehicles

  The major components of the vehicle system element that were contained in the cost estimates included the structure, traction power, electrical equipment, and miscellaneous car equipment. The cost estimates considered the level of the improvement and the types of improvement. The specific types of equipment considered in the various levels of the improvement included the brakes, doors, traction motors, shocks, motor generator sets, compressors, controllers, trucks, the vehicle body, gears, journal bearings, and other items to be included in each improvement project. The items to be considered in each improvement project were then compared with published vehicle modernization, rehabilitation and refurbishment projects. By comparing the specific items to be included in each improvement project with known and published costs, the unit cost per car for each level of improvement was determined. These unit costs per car were then multiplied by the number of cars to be considered in each improvement project.

o Power Distribution

The major components of the power distribution system element that were contained in the cost estimates included the substations, circuit breakers (house-type breaker stations), third rail, coverboard, ducting, cables, overhead wire, poles and foundations, and feeder cables. The unit costs were then developed for each item to be included in the improvement and for each level of improvement and specific project. The quantity of the items proposed to be improved was then multiplied by the unit costs to obtain the final project cost estimate.

o System-Wide Controls

The components of the system-wide controls system element that were contained in the cost estimates included the train operations equipment, train protection equipment, train supervision equipment, cable carriers, telephones, public address systems, radios, data links, CCTV, recording devices, traction power supervision equipment, facilities supervision equipment, and other specific pieces of equipment that were peculiar to a particular transit system. The unit costs were developed for the wayside automatic train protection equipment, hand-carried radios, data link power supervision equipment, communication links, facilities supervision equipment, voice recording equipment, vehicle-borne automatic train protection equipment, data link equipment, CCTV monitors and cameras, telephone systems, data recorders and recording devices, communication cable, vehicle-borne automatic train operation equipment, and other specific types of equipment. These unit costs were then utilized with the specific equipment requirements for each project to obtain a total cost estimate for that project.

o Stations

The components of the station system element that were contained in the cost estimates included the horizontal circulation equipment, vertical circulation equipment, station amenities, fare collection equipment, security system equipment, the interior/exterior finishes, the structures, and the mechanical and electrical equipment contained in the stations. The descriptions of a large number of station projects and associated published cost were then compared to the definitions of the different levels of improvements. This evaluation resulted in the development of unit costs per square foot for each level of improvement and each type of transit system. The unit cost was then multiplied by the quantity (square feet) for each improvement project to obtain a total cost for that project.

- Structures and Facilities

  The components of the structures and facilities system element that were contained in the cost estimates included the superstructure metalwork, concrete decks and beams, safety walks and inspection walkways, the abutment walls and footings, retaining walls, piers and columns, the electrical and mechanical equipment, and other special features. The level of improvement definitions were used to assist in establishing the overall degree of the improvement and the specific types of material and equipment that should be included in the improvement project. Unit costs per square foot were then developed by establishing the type of deck, number of tracks, number of spans, the length of the span and the specific type of bridge being improved in that project. These unit costs were then multiplied by the quantity (square feet) included in each improvement project to obtain a total project cost.

- Maintenance Facilities

  The components of the maintenance facility system element that were contained in the cost estimates included operational features, architectural features, structural features, mechanical features, AC and DC electrical equipment, trackwork, drainage, site lighting, fire protection equipment, and special features. Unit costs were developed for each item proposed to be included in each specific project. The quantity of the items to be improved was then multiplied by the unit cost to obtain a total project cost estimate.

The estimated capital costs for all proposed improvements to each major system element by transit agency are provided in Table 5.2. These costs reflect the transit system condition, provided in Chapter 3, the proposed types of improvements, explained in Chapter 4, and the staging of proposed improvement projects. Although the costs are considered to be representative of the requirements for all segments of each transit system to achieve and maintain the desired standard condition (i.e., either "good" or "excellent"), the actual packaging of improvement projects by transit agencies will likely be different than assumed for this study. For example, a major track project would probably include the implementation of track, structures, signaling and other types of improvements at the same time. Therefore, it may not be appropriate to use individual system element costs as <u>definitive</u> requirements for capital expenditures by any particular transit operating authority.

In addition, the capital costs in Table 5.2 do not include:

- Rail line extensions.
- Expansion of service due to projected increases in rail ridership.
- Improvements such as multi-modal transportation centers, major new station complexes and additional maintenance facilities, etc.
- Special additional elderly and handicapped requirements, such as elevators, ramps, and high-level platforms in stations that do not yet have them.

5.2 COST EFFECTIVENESS PRIORITIZATION CONCEPTS

As previously explained, two different methods of estimating the cost effectiveness of proposed improvements to the different segments were developed. These different methods are explained in the following sections of this report.

TABLE 5.2

ESTIMATED CAPITAL COST FOR PROPOSED IMPROVEMENTS TO EACH MAJOR SYSTEM ELEMENT BY OPERATING AUTHORITY

(Costs in $ Millions)

Type	Operating Authority	System Elements							Total
		Track	Vehicles	Power Distribution	System-Wide Controls	Stations	Structures & Facilities	Maintenance Facilities	
Rapid Rail	MBTA	20.22	37.10	162.10	40.80	74.20	101.47	29.90	465.79
	NYCTA	362.34	813.40	549.79	1,344.70	2,154.31	1,076.80	583.50	6,884.84
	SIRTOA	25.50	5.70	0	62.00	13.20	27.58	16.50	150.48
	PATH	8.58	198.40	24.80	9.50	35.30	100.56	52.70	429.83
	SEPTA	37.11	49.00	56.30	105.60	90.50	122.86	40.10	501.47
	PATCO	23.40	15.30	3.80	12.30	7.80	25.26	7.60	95.45
	CTA	45.55	706.40	89.40	45.90	140.50	448.26	138.60	1,614.60
	GCRTA	32.61	0	0	13.00	27.20	63.02	4.10	139.92
	BART	9.60	116.20	0	42.80	48.09	6.70	0	223.29
	WMATA	.28	24.30	12.00	24.80	25.90	15.17	8.50	110.95
	MARTA	2.21	0	0	2.80	24.70	1.60	1.90	33.21
Light Rail	MBTA	10.05	114.40	98.50	41.20	16.30	38.06	8.80	327.31
	NJTC	.21	2.50	3.60	2.30	0	.31	.30	9.21
	SEPTA	64.51	191.90	49.20	21.50	17.50	19.58	29.70	393.90
	PAAC	23.49	17.40	17.80	18.10	2.80	.96	0	80.55
	GCRTA	0	4.40	0	4.20	0	39.33	0	47.93
	MUNI	65.09	43.40	0	14.20	4.20	1.23	2.90	131.01
	MTDB	6.16	0	0	0	0	0	.60	6.76
	New Orleans RTA	20.99	0	0	0	0	0	4.80	25.79
Commuter Rail	MBTA	224.90	190.00	0	34.70	10.70	82.90	36.60	579.80
	LIRR	118.34	222.70	46.50	210.20	24.50	251.02	172.60	1,045.87
	Metro-North	231.90	42.30	133.30	266.60	71.20	229.61	176.50	1,151.41
	NJTC	158.01	133.50	30.80	16.78	150.50	252.42	35.20	777.21
	SEPTA	124.75	131.60	189.80	248.20	66.90	388.12	88.40	1,237.77
	PAAC	9.98	1.30	0	1.60	2.10	2.55	0	17.53
	RTA BN	0	55.50	0	6.10	5.60	13.15	19.70	100.05
	RTA C&NW	86.41	81.90	0	22.90	19.80	85.09	29.20	325.30
	RTA ICG	46.57	70.40	61.10	25.00	116.80	36.89	26.80	383.55
	RTA RI	41.07	13.50	0	34.10	5.90	63.79	39.20	197.55
	RTA MR	70.41	27.00	0	27.40	16.30	35.56	30.80	207.47
	RTA Norfolk & Western	0	3.00	0	0	2.40	0	.50	5.90
	RTA/NICTD	29.72	8.80	48.70	0	3.00	14.62	0	104.84
	MARC	0	26.20	0	0	1.50	0	0	27.70
	CALTRANS Southern Pacific	0	23.80	0	0	18.10	0	0	41.90
Total Estimated Costs		1,899.93	3,371.30	1,577.50	2,699.28	3,197.69	3,544.45	1,586.00	17,876.14
Percent of Total Costs		10%	19%	9%	15%	18%	20%	9%	100%

NOTE: This table provides improvement costs by element and transit system as estimated in improvement projects. Each project was assigned to one system, even though some systems share such elements as power distribution and stations (MBTA RR and LR, GCRTA RR and LR, NJTC CR and Metro North CR). In Chapter 5, the costs and benefits for these system elements have been distributed appropriately for shared transit systems.

5.2.1 PASSENGER UTILIZATION VERSUS CAPITAL COSTS

This method of determining the priority of proposed improvements provides an estimate of the passenger utilization on each segment, in terms of passenger miles, and the related capital cost. The ratio of passenger miles to capital cost provides an estimate of the value of the proposed improvements and assumes that segments/branches which have heavy utilization should have priority over segments/branches that are not heavily utilized, for the same capital cost.

5.2.2 OPERATING COST SAVINGS AND PASSENGER BENEFITS

An alternative method of determining the priority of proposed improvements to the different transit system segments/branches was also employed. The general procedure includes the utilization of unit operating cost saving and passenger benefit modifiers. These modifiers include an annual operating cost savings and an annual passenger benefit due to proposed improvements on each system element for each proposed improvement project.

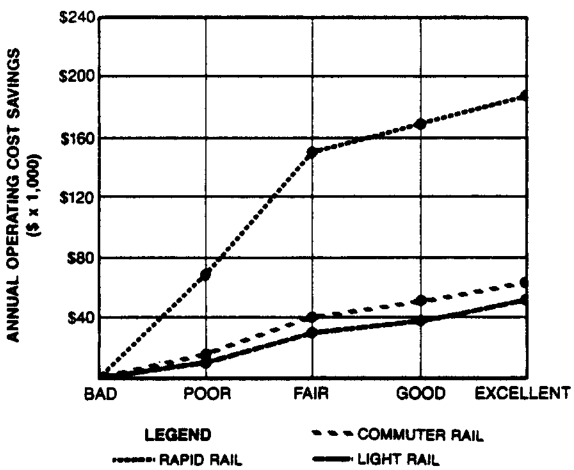
The premise of this analysis is that there are reductions in operating costs and increases in passenger benefits in dollars that are associated with physical improvements to the transit systems. That is, when the track, vehicles, power distribution systems, etc., are improved from "bad/poor" to "good", there is an expectation of corresponding reductions in maintenance costs, and that existing riders would experience a reduction in time and therefore realize an increase in social benefits.

The operating cost savings and passenger benefits have been designed so that they can be multiplied by indicators of the magnitude of the improvement and change in condition. The indicators include the miles of track, numbers of vehicles, miles of third rail/catenary, number of substations, station area, structure area, length of tunnel, and the maintenance facility and yard areas being improved. When the modifiers are multiplied by the magnitude of each proposed improvement, the result is an annual benefit. An estimate of the total value of the benefits was then obtained by multiplying the annual benefits by a present value multiplier, which was estimated by determining the life remaining after the improvement. (NOTE: A 10 percent per year discount rate was used to obtain the present value multipliers.) The passenger benefits also include consideration of the utilization of each segment/branch in terms of passenger miles.

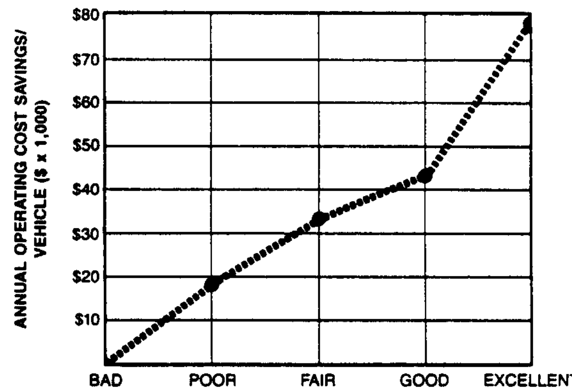
The annual operating cost savings and passenger benefits are illustrated on the diagrams, which follow. The actual values used in the calculations and the rationale for the values is provided in an Appendix to this report. The modifiers were developed for the following system elements/subsystems:

- Track
- Vehicles
- Power
  - Substations
  - Third Rail
  - Overhead Wire/Catenary
- System-Wide Controls
- Stations
  - Subway
  - Other
- Structures
  - Bridges
  - Elevated Railway
  - Tunnel
- Maintenance Facility
  - Buildings
  - Yards

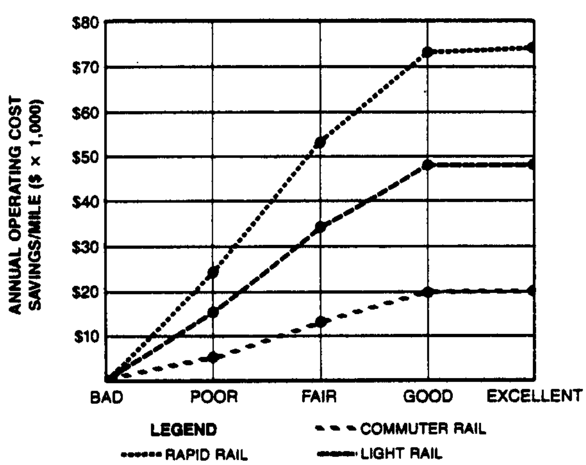
ANNUAL OPERATING COST SAVINGS/ TRACK MILE FOR TRACK



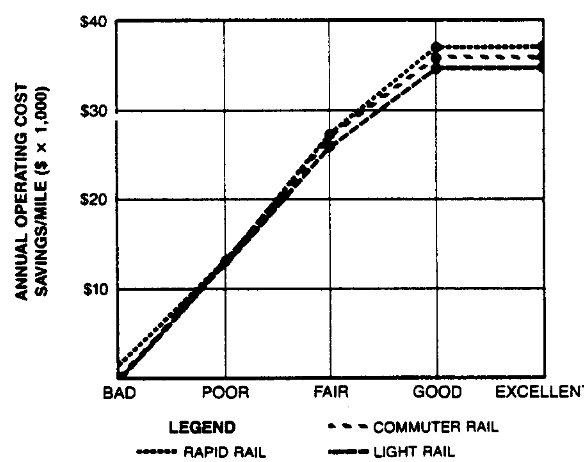
ANNUAL OPERATING COST SAVINGS/VEHICLE



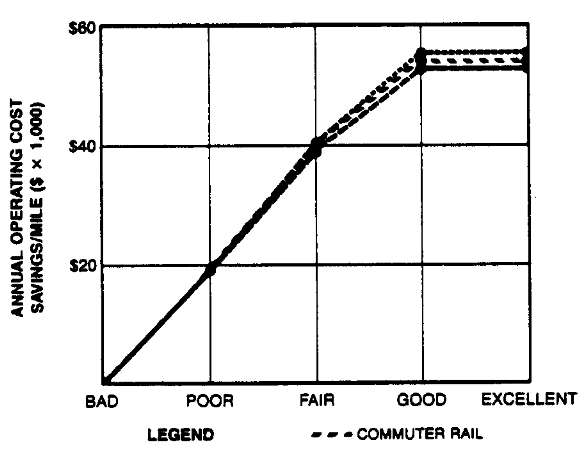
ANNUAL OPERATING COST SAVINGS/MILE FOR SUBSTATIONS



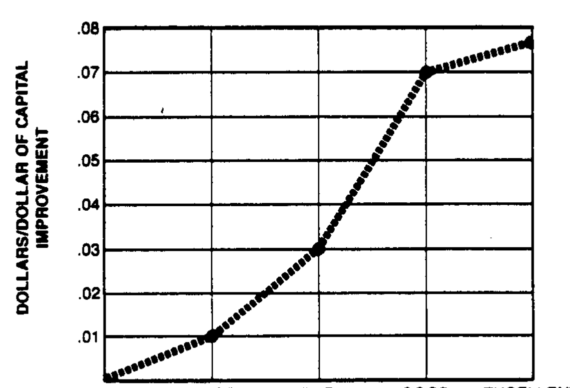
ANNUAL OPERATING COST SAVINGS/MILE FOR THIRD RAIL

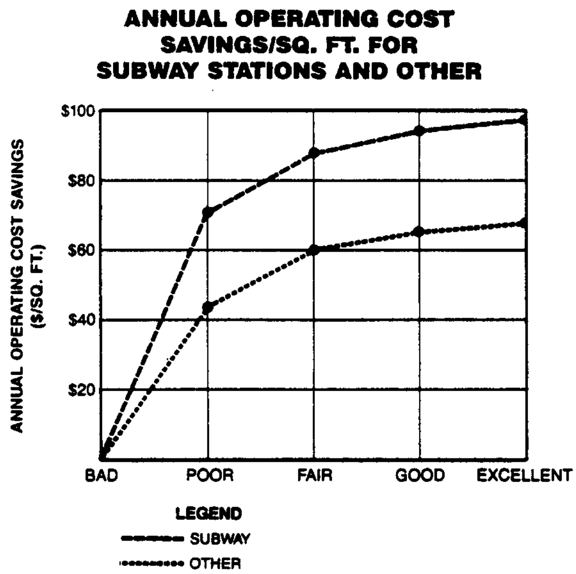


ANNUAL OPERATING COST SAVINGS FOR OVERHEAD WIRE/MILE

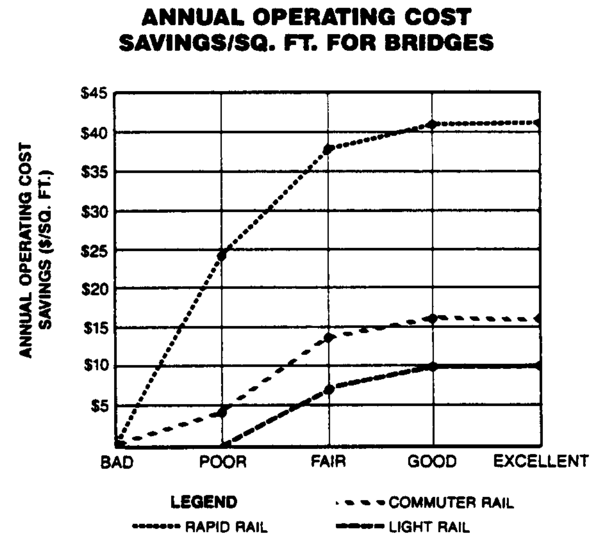


ANNUAL OPERATING COST SAVINGS FOR SWC

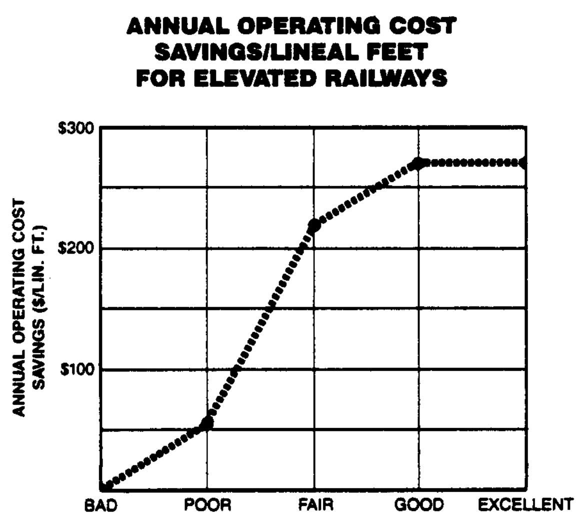




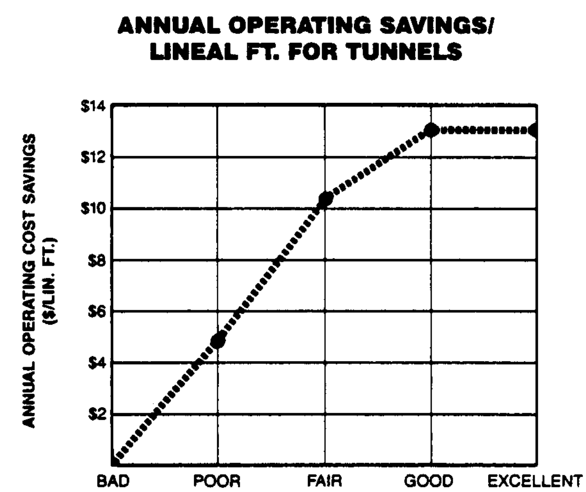
ANNUAL OPERATING COST SAVINGS/SQ. FT. FOR SUBWAY STATIONS AND OTHER
ANNUAL OPERATING COST SAVINGS ($/SQ. FT.)
$100
$80
$60
$40
$20
BAD
POOR
FAIR
GOOD
EXCELLENT
LEGEND
SUBWAY
OTHER



ANNUAL OPERATING COST SAVINGS/SQ. FT. FOR BRIDGES
ANNUAL OPERATING COST SAVINGS ($/SQ. FT.)
$45
$40
$35
$30
$25
$20
$15
$10
$5
BAD
POOR
FAIR
GOOD
EXCELLENT
LEGEND
COMMUTER RAIL
RAPID RAIL
LIGHT RAIL



ANNUAL OPERATING COST SAVINGS/LINEAL FEET FOR ELEVATED RAILWAYS
ANNUAL OPERATING COST SAVINGS ($/LIN. FT.)
$300
$200
$100
BAD
POOR
FAIR
GOOD
EXCELLENT



ANNUAL OPERATING SAVINGS/ LINEAL FT. FOR TUNNELS
ANNUAL OPERATING COST SAVINGS ($/LIN. FT.)
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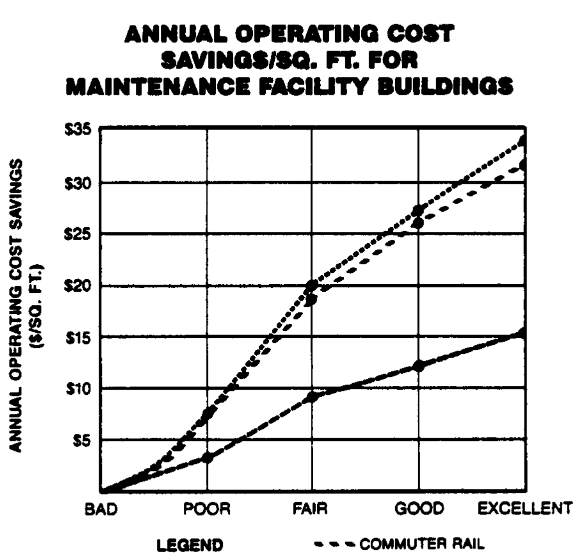
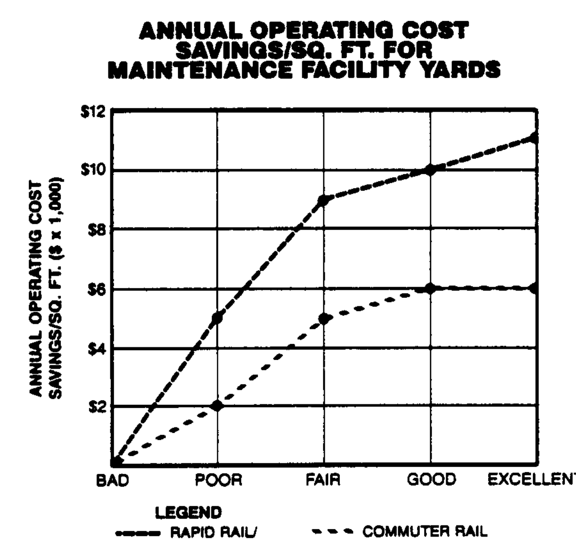
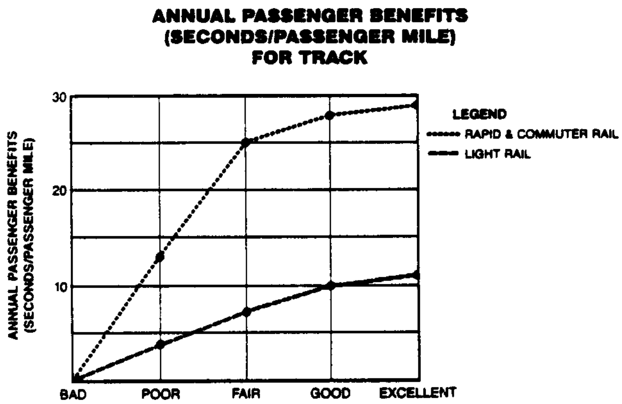
$12
$10
$8
$6
$4
$2
BAD
POOR
FAIR
GOOD
EXCELLENT

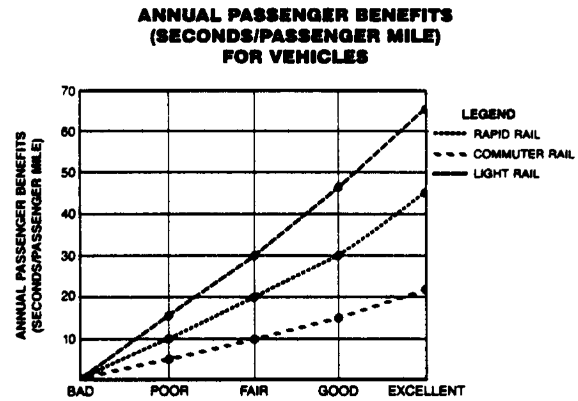


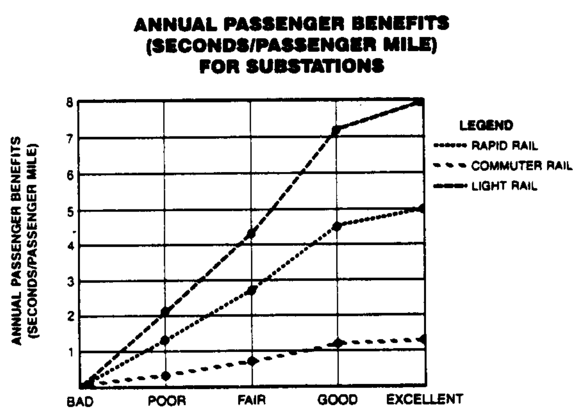
ANNUAL OPERATING COST SAVINGS/SQ. FT. FOR MAINTENANCE FACILITY BUILDINGS
ANNUAL OPERATING COST SAVINGS ($/SQ. FT.)
$35
$30
$25
$20
$15
$10
$5
BAD
POOR
FAIR
GOOD
EXCELLENT
LEGEND
COMMUTER RAIL
RAPID RAIL
LIGHT RAIL

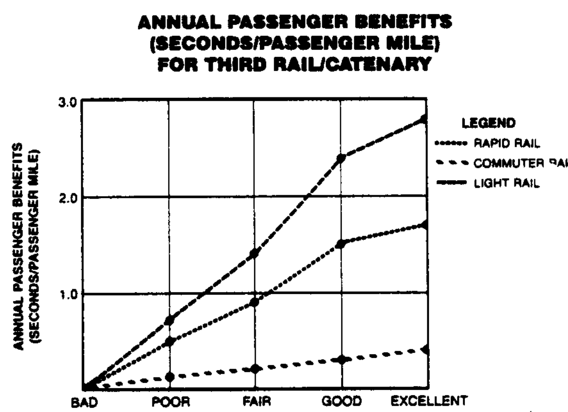


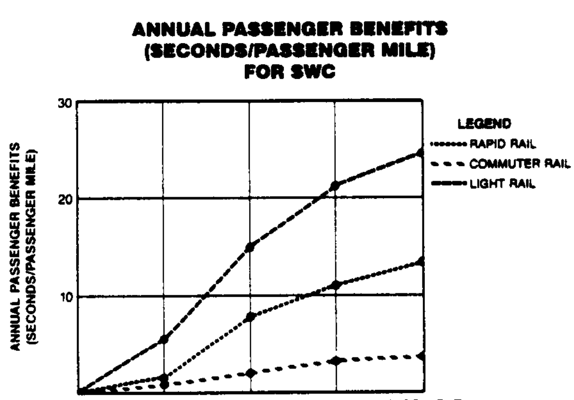
ANNUAL OPERATING COST SAVINGS/SQ. FT. FOR MAINTENANCE FACILITY YARDS
ANNUAL OPERATING COST SAVINGS/SQ. FT. ($ x 1,000)
$12
$10
$8
$6
$4
$2
BAD
POOR
FAIR
GOOD
EXCELLENT
LEGEND
RAPID RAIL/ LIGHT RAIL
COMMUTER RAIL


ANNUAL PASSENGER BENEFITS
(SECONDS/PASSENGER MILE)
FOR TRACK
LEGEND
RAPID & COMMUTER RAIL
LIGHT RAIL
ANNUAL PASSENGER BENEFITS (SECONDS/PASSENGER MILE)
30
20
10
BAD
POOR
FAIR
GOOD
EXCELLENT


ANNUAL PASSENGER BENEFITS
(SECONDS/PASSENGER MILE)
FOR VEHICLES
LEGEND
RAPID RAIL
COMMUTER RAIL
LIGHT RAIL
ANNUAL PASSENGER BENEFITS (SECONDS/PASSENGER MILE)
70
60
50
40
30
20
10
BAD
POOR
FAIR
GOOD
EXCELLENT


ANNUAL PASSENGER BENEFITS
(SECONDS/PASSENGER MILE)
FOR SUBSTATIONS
LEGEND
RAPID RAIL
COMMUTER RAIL
LIGHT RAIL
ANNUAL PASSENGER BENEFITS (SECONDS/PASSENGER MILE)
8
7
6
5
4
3
2
1
BAD
POOR
FAIR
GOOD
EXCELLENT


ANNUAL PASSENGER BENEFITS
(SECONDS/PASSENGER MILE)
FOR THIRD RAIL/CATENARY
LEGEND
RAPID RAIL
COMMUTER RAIL
LIGHT RAIL
ANNUAL PASSENGER BENEFITS (SECONDS/PASSENGER MILE)
3.0
2.0
1.0
BAD
POOR
FAIR
GOOD
EXCELLENT


ANNUAL PASSENGER BENEFITS
(SECONDS/PASSENGER MILE)
FOR SWC
LEGEND
RAPID RAIL
COMMUTER RAIL
LIGHT RAIL
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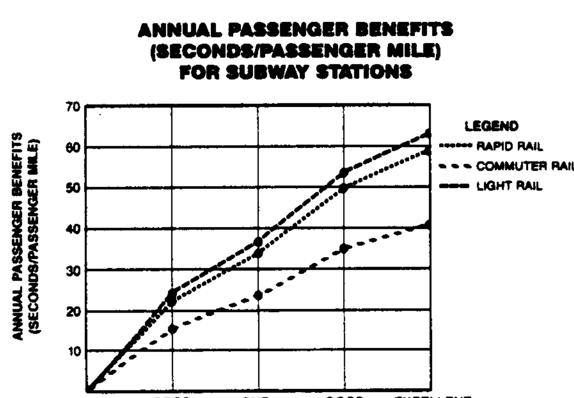
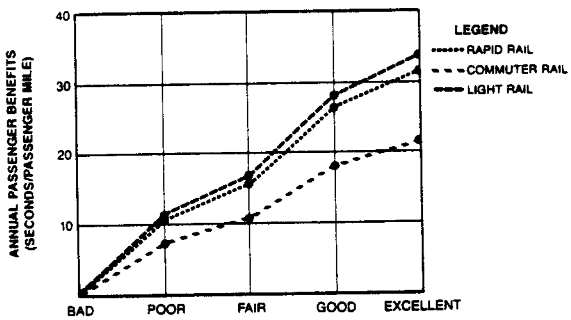
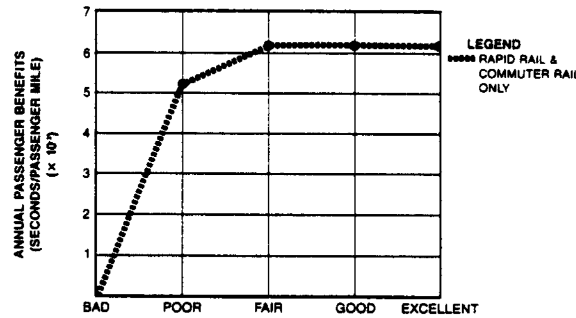
30
20
10
BAD
POOR
FAIR
GOOD
EXCELLENT


ANNUAL PASSENGER BENEFITS
(SECONDS/PASSENGER MILE)
FOR SUBWAY STATIONS
LEGEND
RAPID RAIL
COMMUTER RAIL
LIGHT RAIL
ANNUAL PASSENGER BENEFITS (SECONDS/PASSENGER MILE)
70
60
50
40
30
20
10
BAD
POOR
FAIR
GOOD
EXCELLENT

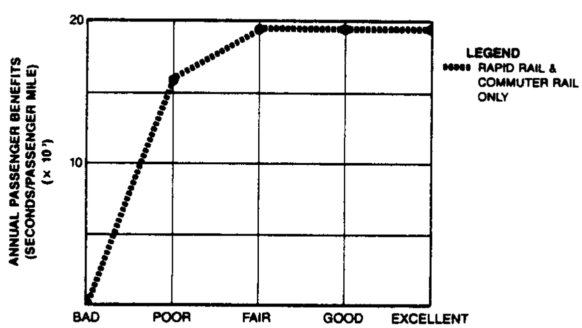
ANNUAL PASSENGER BENEFITS
(SECONDS/PASSENGER MILE)
FOR OTHER STATIONS



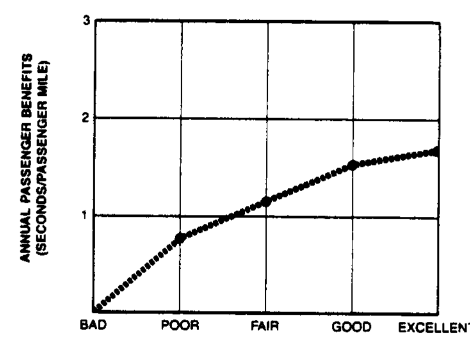
ANNUAL PASSENGER BENEFITS
(SECONDS/PASSENGER MILE)
FOR BRIDGES



ANNUAL PASSENGER BENEFITS
(SECONDS/PASSENGER MILE)
FOR ELEVATED RAILWAYS



ANNUAL PASSENGER BENEFITS
(SECONDS/PASSENGER MILE)
FOR MAINTENANCE FACILITY BUILDINGS



5.3 TRANSIT SYSTEM SEGMENTS

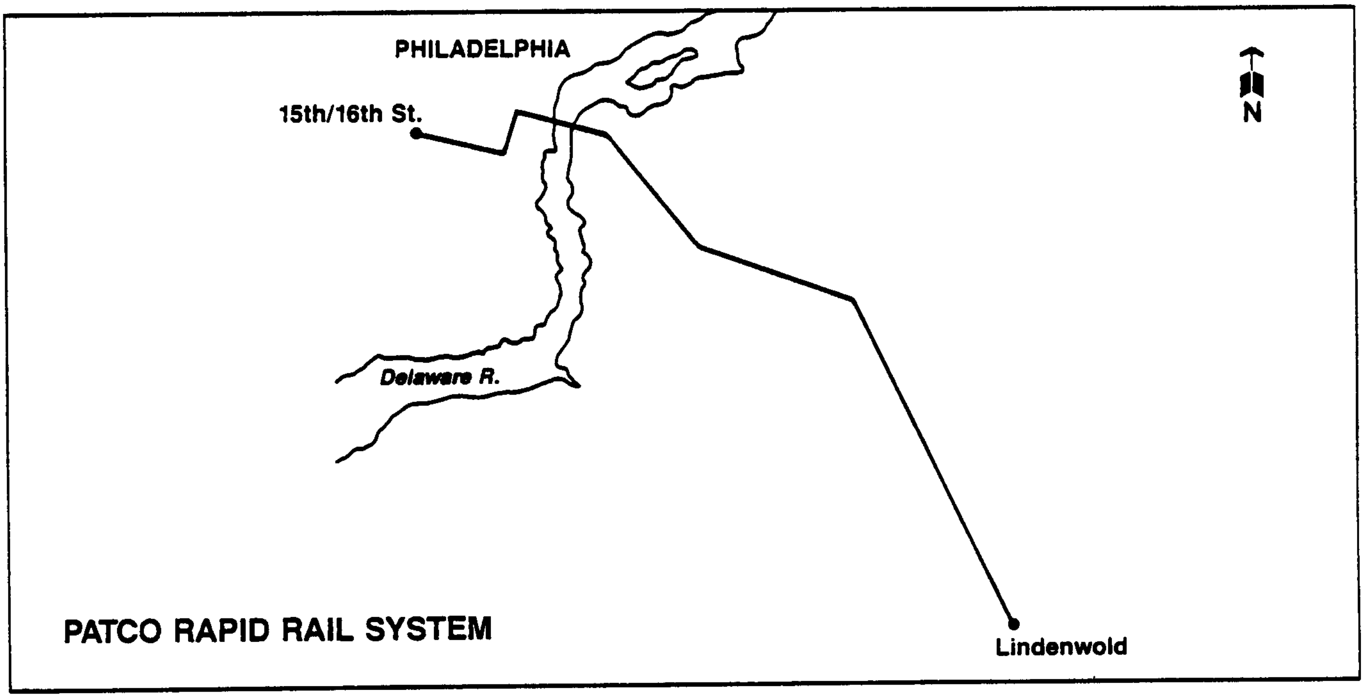
In order to estimate the effectiveness or benefits associated with proposed improvements, it was necessary to first develop a set of segments for analysis on each rapid rail, light rail, and commuter transit system. These segments consist of identifiable and logical portions of each transit system. The resulting numbers of segments by major rail area and type of transit system are provided in Table 5.3. Although it was intended to maintain the separation of these segments by type of transit system, in certain situations it was necessary to combine these systems for analysis when the total number of segments was too small and funding was likely to be through the same transit authority. For example, the segments on the New Jersey Transit Corporation light rail and commuter systems were considered together, as were those on the Cleveland GCRTA light rail and rapid rail systems, the New York City Metropolitan Transit Authority rapid rail systems, the New York City commuter rail systems, and the Chicago commuter rail systems. The Philadelphia and Pittsburgh light rail systems were also considered together since all state and local funding is provided from the Pennsylvania General Fund.

A description of the segmentation of each of the transit systems is provided in the following diagrams. These descriptions include the segment designation, segment title, initial and terminal stations and associated track miles.

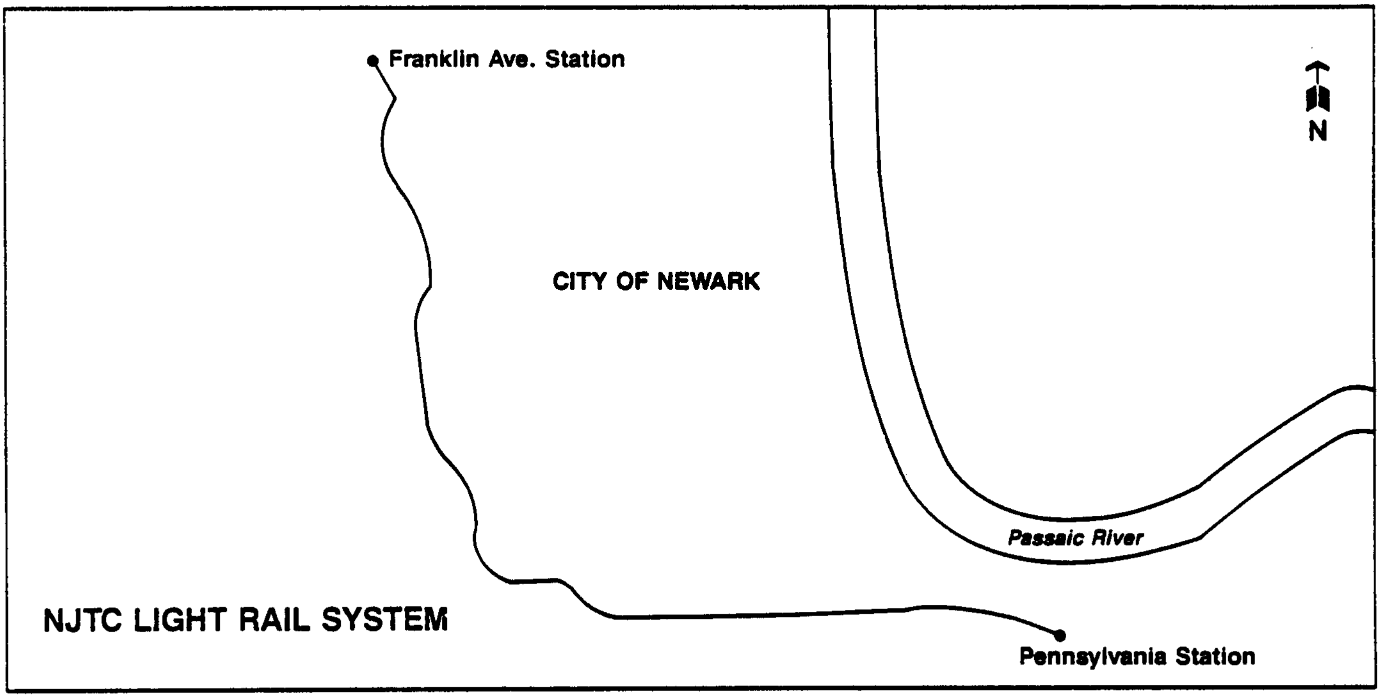
TABLE 5.3

Number of Segments By Major Rail Area and Type of Transit System

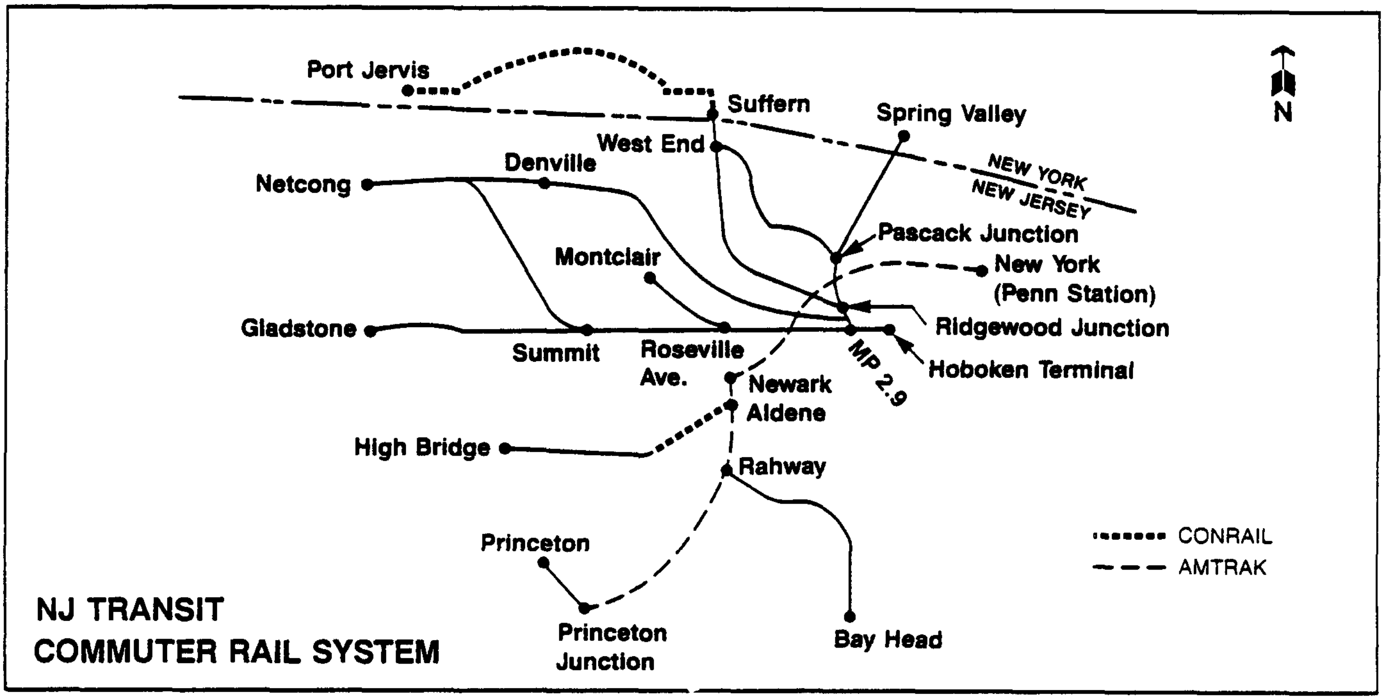
Major Rail Area	Type of Transit System	Number of Segments	Total Number of Segments
Boston	Rapid Rail	6	6
	Light Rail	7	7
	Commuter Rail	10	10
New York	Rapid Rail		
	- NYCTA	41	
	- SIRTOA	1	
	Subtotal		42
	Commuter Rail		
	- LIRR	16	
	- Metro North	9	
	Subtotal		25
New York/Northern NJ	Rapid Rail	5	5
	Light Rail	1	
	Commuter Rail	12	
	Subtotal		13
Southern NJ/ Philadelphia/Pittsburgh	Rapid Rail		
	- PATCO	1	
	- SEPTA	5	
	Subtotal		6
	Light Rail		
	- SEPTA	6	
	- PAAC	3	
	Subtotal		9
	Commuter Rail		
	- SEPTA	14	
	- PAAC	1	
	Subtotal		15
Washington DC	Rapid Rail	4	4
	Commuter Rail	3	3
Chicago	Rapid Rail	7	7
	Commuter Rail		
	- BN	1	
	- C&NW	3	
	- ICG	4	
	- RI	1	
	- MR	2	
	- N&W	1	
	- CSS&SB	1	
	Subtotal		13
Cleveland	Rapid Rail	2	
	Light Rail	1	
			3
Atlanta	Rapid Rail	4	4
New Orleans	Light Rail	1	1
San Francisco/San Diego	Rapid Rail	5	5
	Light Rail		
	- MUNI	6	
	- MTDB	1	
	Subtotal		7
	Commuter Rail	1	1
TOTAL			186



Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
1.1	Lindenwold Line	15th/16th Street	Lindenwold	29.0

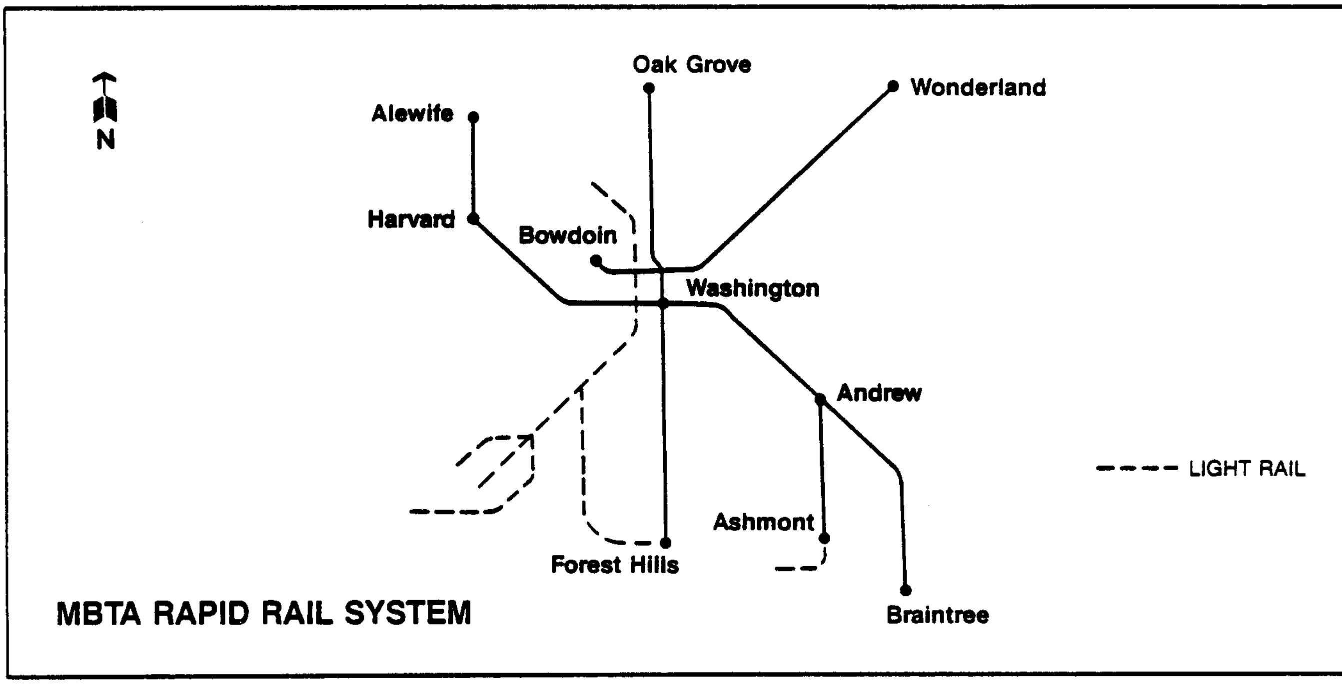


Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
2.1	NJTC Light Rail	Franklin Ave. Station	Pennsylvania Station	8.5

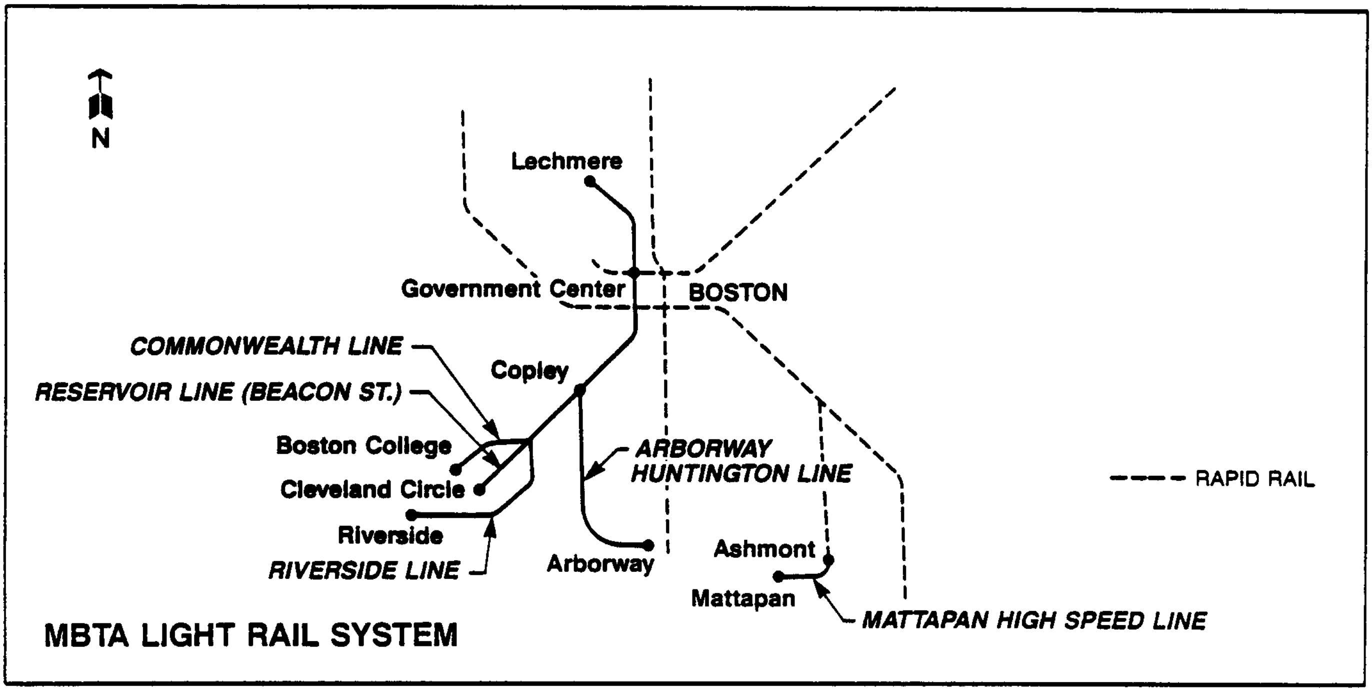


Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
3.1	Raritan Valley Line	High Bridge	Aldene	65.7
3.2	Princeton Line	Princeton	Princeton Junction	3.5*
3.3	North Jersey Coast Line	Bay Head	Rahway	77.3
3.4	Susquehanna Mainline	Suffern	Hoboken Terminal	94.2
3.5	Bergen County Line	Ridgewood Junction	West End	32.0
3.6	Pascack Valley Line	Pascack Junction	Spring Valley	27.5
3.7	Boonton Line	MP 2.9 on the Morristown Line	Denville	49.1
3.8	Morristown Line	Hoboken Terminal	Netcong	105.0
3.9	Montclair Branch	Roseville Avenue	Montclair	7.6
3.10	Gladstone Branch	Gladstone	Summit	23.0
3.11	Port Jervis Branch	Suffern	Port Jervis	85.3*
3.12	Northeast Corridor Line	Princeton Junction	Newark	76.6*

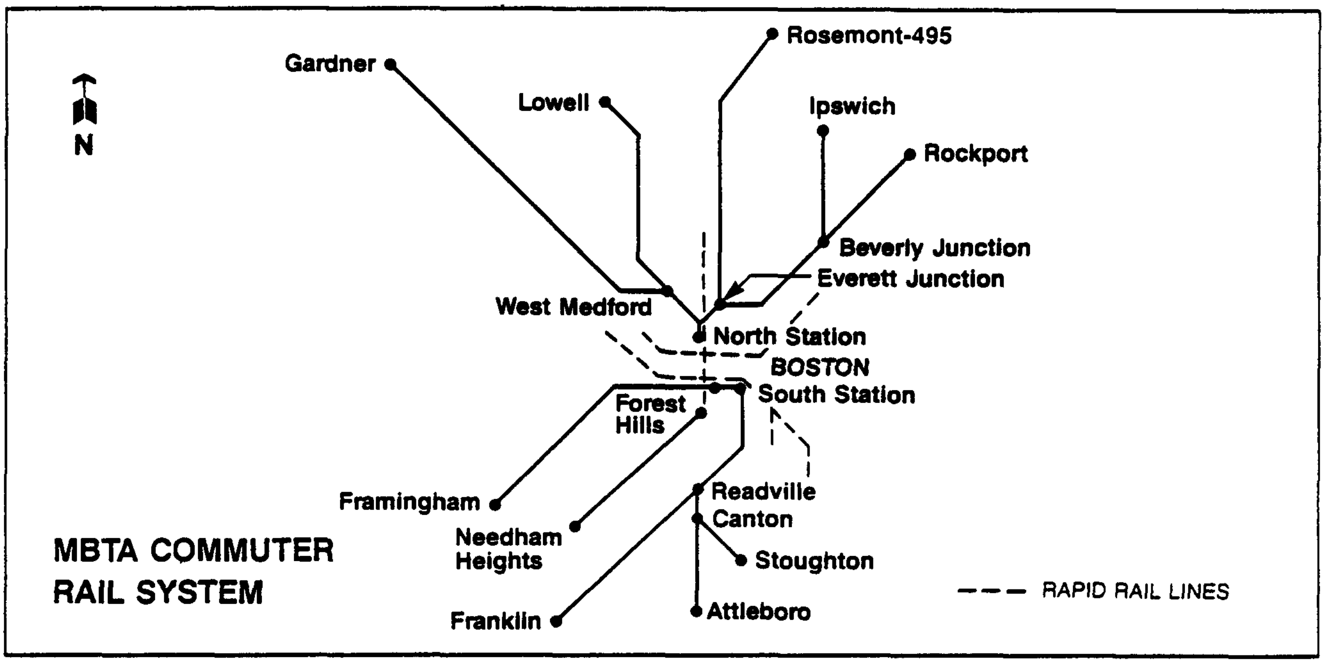
*Not the responsibility of NJTC.



Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
4.1	Red Line North	Alewife	Andrew	17.8
4.2	Red Line South	Andrew	Braintree	20.9
4.3	Red Line - Ashmont Branch	Ashmont	Andrew	8.8
4.4	Blue Line	Wonderland	Bowdoin	13.6
4.5	Orange Line South	Forest Hills	Washington	9.3
4.6	Orange Line North	Washington	Oak Grove	12.5

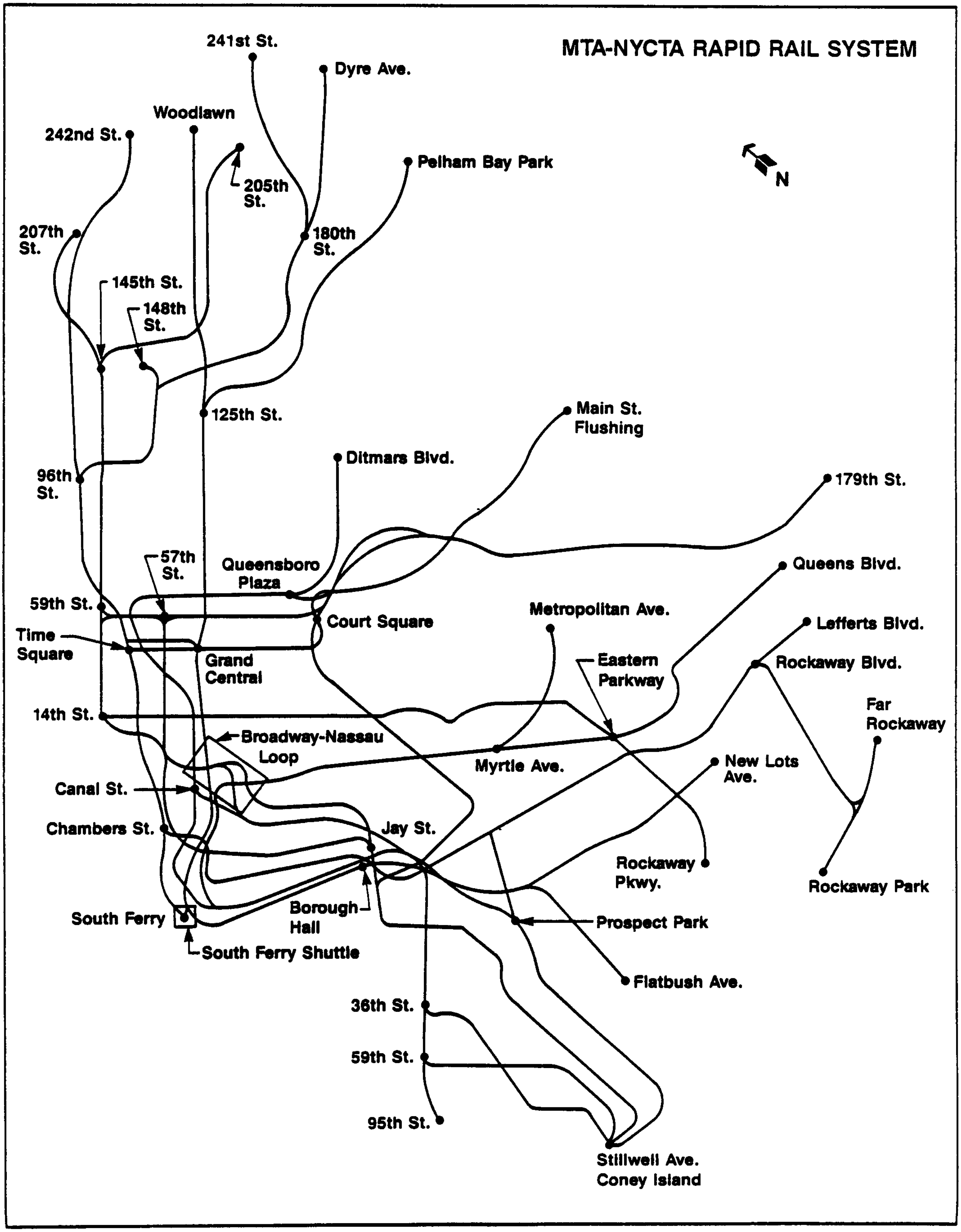


Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
5.1	Commonwealth Line	Boston College	Blandford St. portal	8.12
5.2	Reservoir Line	Cleveland Circle	St. Mary's portal	5.93
5.3	South Mainline	Blandford St. portal	Government Center	4.20
5.4	North Mainline	Government Center	Lechmere	3.60
5.5	Riverside Line	Riverside	Fenway Park portal	18.60
5.6	Arborway-Huntington Line	Arborway	Copley	9.70
5.7	Mattapan-Ashmont Branch	Mattapan	Ashmont	5.20



Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
6.1	Fitchburg Mainline	Gardner	North Station	121.25
6.2	New Hampshire Mainline	Lowell	West Medford	51.00
6.3	West Route Mainline	Rosemont	North Station	53.50
6.4	East Route Mainline	Ipswich	Everett Junction	43.90
6.5	Gloucester Branch	Rockport	Beverly Junction	29.40
6.6	Stoughton Branch	Stoughton	Canton	4.00
6.7	Franklin Branch	Franklin	Readville	23.30
6.8	Needham Branch	Forest Hills	Needham Heights	17.00
6.9	Boston & Albany Line	Framingham	South Station	44.00*
6.10	Shore Line	South Station	Attleboro	83.00*

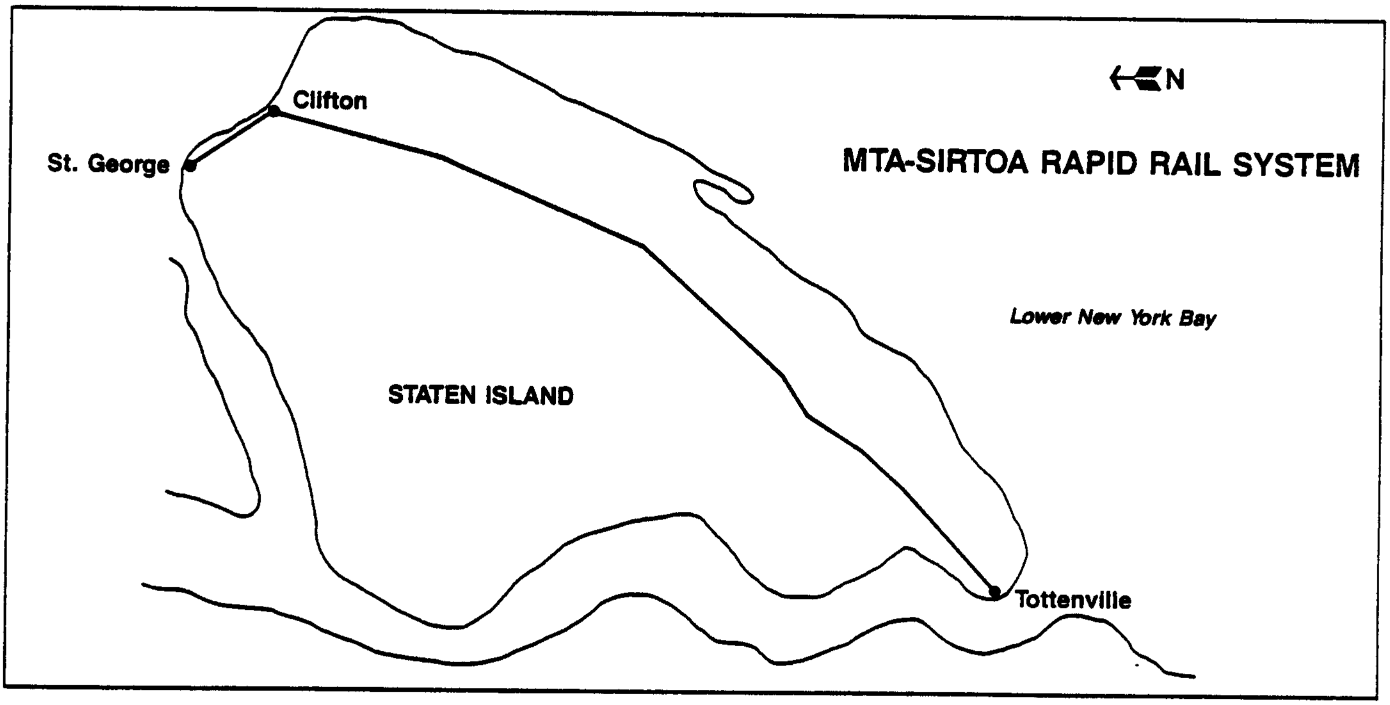
*Track owned and maintained by Conrail.


MTA-NYCTA RAPID RAIL SYSTEM
N
241st St.
Dyre Ave.
Woodlawn
242nd St.
205th St.
Pelham Bay Park
207th St.
180th St.
145th St.
148th St.
125th St.
Main St. Flushing
Ditmars Blvd.
96th St.
179th St.
57th St.
Queensboro Plaza
Queens Blvd.
59th St.
Court Square
Metropolitan Ave.
Lefferts Blvd.
Time Square
Grand Central
Eastern Parkway
Rockaway Blvd.
14th St.
Far Rockaway
Broadway-Nassau Loop
Myrtle Ave.
New Lots Ave.
Canal St.
Jay St.
Chambers St.
Rockaway Pkwy.
Rockaway Park
South Ferry
Borough Hall
Prospect Park
South Ferry Shuttle
Flatbush Ave.
36th St.
59th St.
95th St.
Stillwell Ave. Coney Island

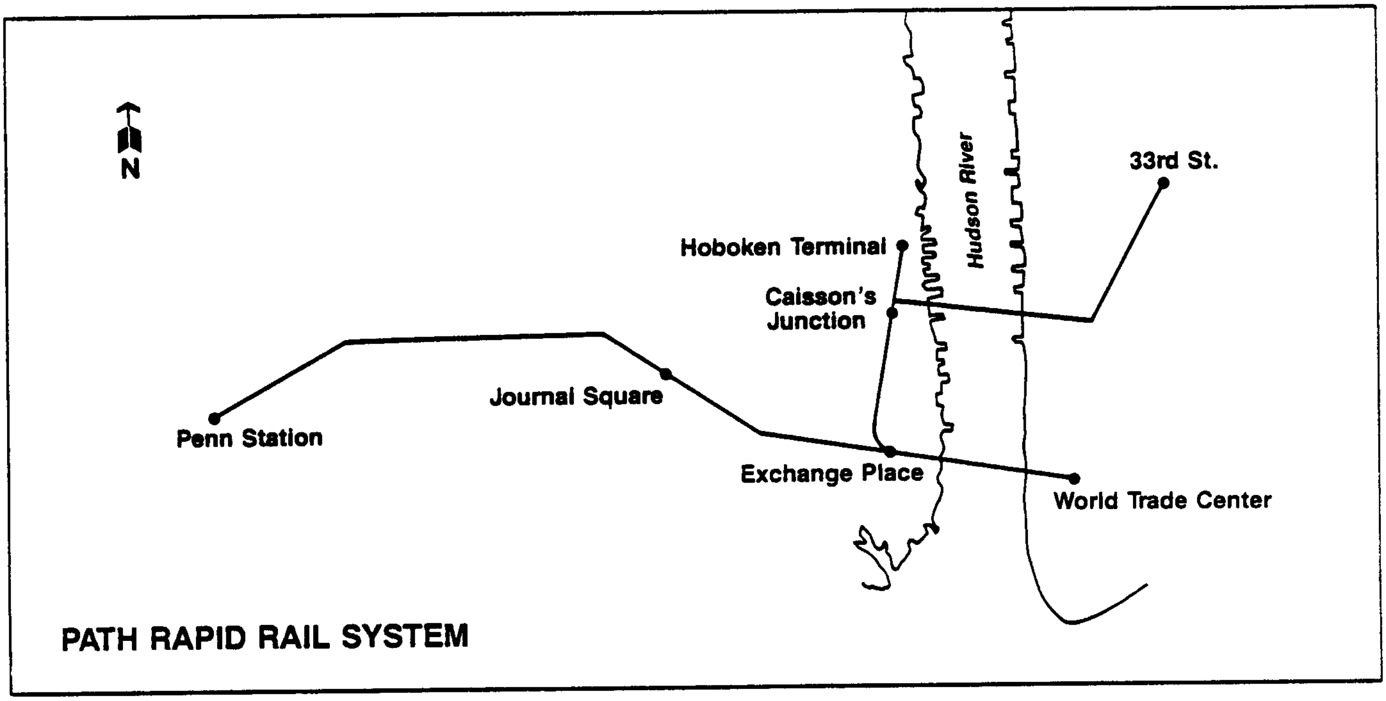
Segment Designation	Segment	Initial Point		Terminal Point	Track Miles
7.1	Broadway-7th Avenue Line	96th Street		242nd Street	21.5
7.2	Lenox Avenue Line/ White Plains Line	96th St./Broadway		148th St./Lenox Terminal	8.6
			and		
		145th Street		3rd Avenue Portal	
7.3	White Plains Line	3rd Ave. Portal		East 180th St./ West Chester Ave.	9.6
7.4	White Plains Line	East 180th Street		241 St./White Plains Road	13.4
7.5	Dyre Avenue Line	East 180th Street		Dyre Avenue	13.8
7.6	Lexington Avenue Line	Woodlawn		125th Street	19.2
7.7	Pelham Bay Park Line	125th St./Lexington		Pelham Bay Park	22.3
7.8	Broadway - 7th Ave. Line/Clark St. Line	96th St./Broadway		Borough Hall	28.3
7.9	Lexington Ave. Line	125th St./Lexington		Borough Hall	34.7
7.10	New Lots Line	Borough Hall		Sutter Ave. Portal	16.7
7.11	New Lots Line	Sutter Ave. Portal/ Eastern Parkway		New Lots	5.4
7.12	Nostrand Avenue Line	Flatbush/Nostrand		Franklin Ave./ Eastern Parkway	5.3
7.13	Broadway - 7th Ave. Line (South Ferry Branch)	South Ferry		Chambers	1.4
7.14	South Ferry Shuttle				0.8
7.15	Broadway-Nassau Loop	Broadway-Lafayette Street		Essex Street	3.1
			and		
		Broadway-Lafayette Street		Grand Street	
7.16	Astoria Line	Ditmars		60th St. Portal/ Queensboro Plaza	7.6

Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
7.17	Broadway Line	60th St. Portal/ Queensboro Plaza	Canal St./Broadway	17.1
7.18	Broadway Line	Canal Street	Dekalb (Montague Tunnel)	8.4
7.19	Brighton Beach Line	Canal Street	Prospect Park (Manhattan Bridge)	10.6
7.20	Jamaica Avenue Line	Whitehall Street	Essex Portal	6.5
7.21	Jamaica Avenue Line	Essex	Eastern Parkway	14.0
7.22	Jamaica Avenue Line	Broadway/Eastern Parkway	Queens Boulevard	12.2
7.23	Myrtle Avenue Line	Broadway/Myrtle	Metropolitan Ave.	5.6
7.24	4th Avenue Line	Dekalb	4th Ave./95th St.	18.1
7.25	West End Line	36th St./4th Ave.	Coney Island	17.8
7.26	Sea Beach Line	59th St./4th Ave.	Coney Island	18.0
7.27	Brighton Line	Prospect Park	Coney Island	27.6
7.28	Bronx Concourse Line	145th St./St. Nicholas Ave.	205th Street	18.8
7.29	8th Avenue Line	145th St./St. Nicholas Ave.	207th St./Broadway ("A" Train)	10.3
7.30	8th Avenue Line	145th St./St. Nicholas Ave.	8th Ave./59th St.	18.3
7.31	Queens Blvd. Line	179th St./Hillside	8th Ave./53rd St.	46.1
7.32	6th Avenue Line/ Houston-Essex Streets Line	6th Ave./57th St.	Jay St., Brooklyn	18.9
7.33	8th Avenue Line	8th Ave./59th St.	Jay St., Brooklyn	21.8
7.34	Prospect Park Line	Jay St., Brooklyn	Coney Island	31.8
7.35	8th Avenue Line	Jay St., Brooklyn	Lefferts	35.3

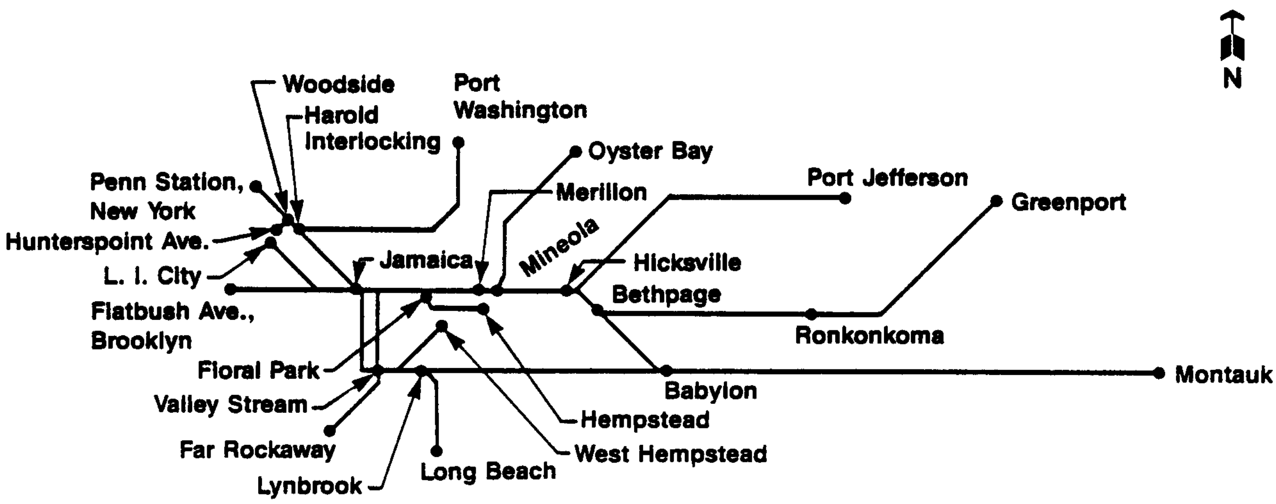
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
7.36	Brooklyn Crosstown Line	Court Square	Bergen St.	14.0
7.37	Flushing Line	Times Square	Main St./Flushing	24.6
7.38	Canarsie Line	8th Ave./14th St.	Rockaway Parkway	21.3
7.39	Franklin Shuttle	Franklin Avenue	Prospect Park	2.6
7.40	Times Square Shuttle	Grand Central	Times Square/42nd Street	2.1
7.41	Rockaway Line	Rockaway Blvd.	Rockaway Park and Far Rockaway	27.0



Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
8.1	Staten Island Rapid Transit	St. George	Tottenville	28.7



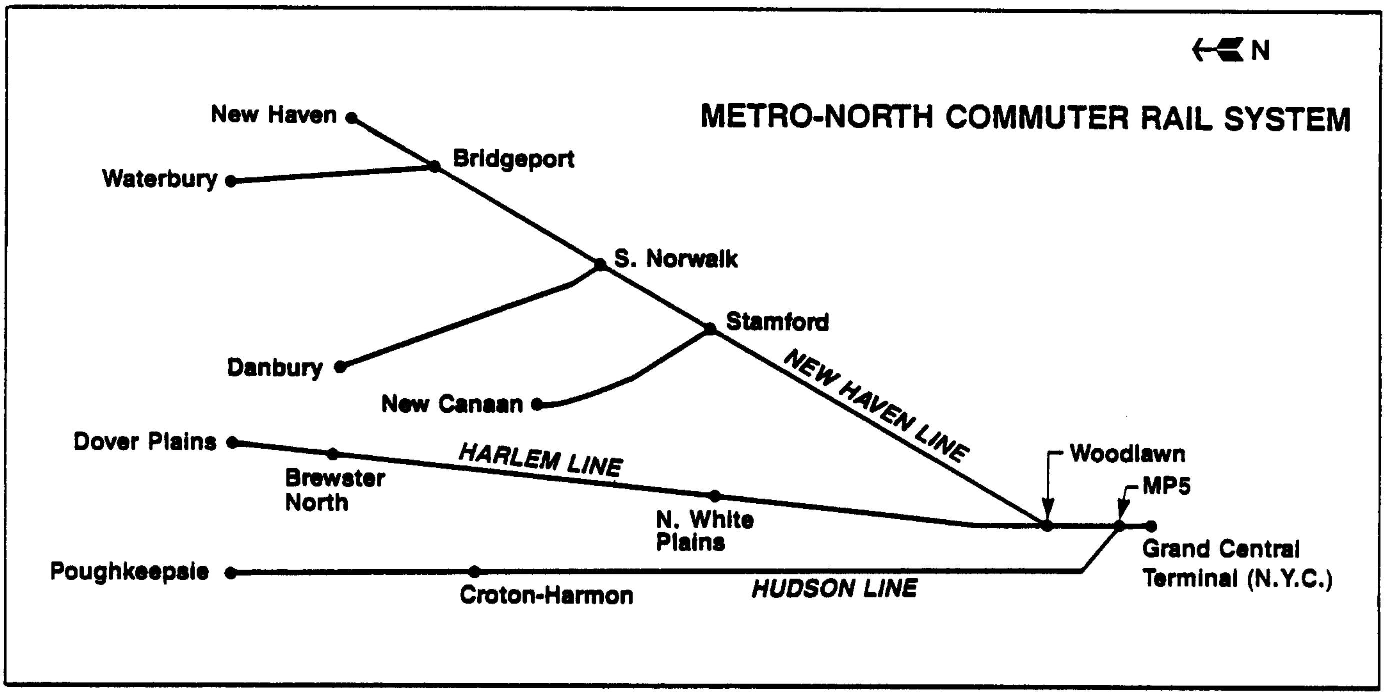
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
9.1	Uptown/Hoboken Branch	33rd Street	Hoboken Terminal	7.68
9.2	Hoboken Branch	Caisson's Junction	Exchange Place	2.91
9.3	Downtown Branch	Exchange Place	World Trade Center	2.50
9.4	Journal Square Branch	Exchange Place	portal near Journal Square	2.95
9.5	Newark Branch	portal near Journal Square	Penn Station	12.80



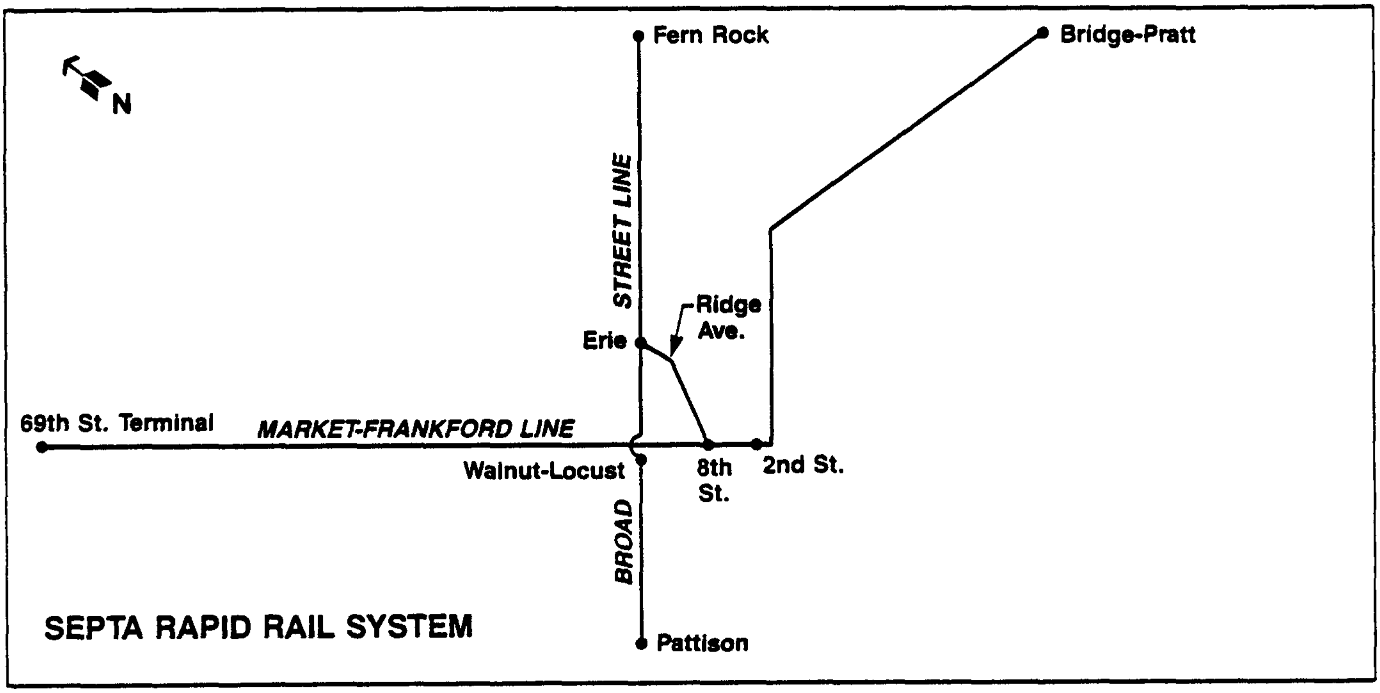
MTA-LONG ISLAND COMMUTER RAIL SYSTEM

Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
10.1	Port Washington Branch	Port Washington	Harold Interlocking	28.4
10.2	Port Jefferson Branch	Port Jefferson	Hicksville	39.3
10.3	Mainline	Hicksville	Ronkonkoma	30.1
10.4	Mainline	Jamaica	Floral Park	27.2
10.5	Oyster Bay Branch	Oyster Bay	Mineola	24.7
10.6	Hempstead Branch	Hempstead	Floral Park	10.1
10.7	Far Rockaway Branch	Far Rockaway	Valley Stream	9.6
10.8	Babylon Branch	Babylon	Valley Stream	40.8
10.9	Long Beach Branch	Long Beach	Lynbrook	14.2
10.10	West Hempstead Branch	West Hempstead	intersection with Babylon Branch	4.3

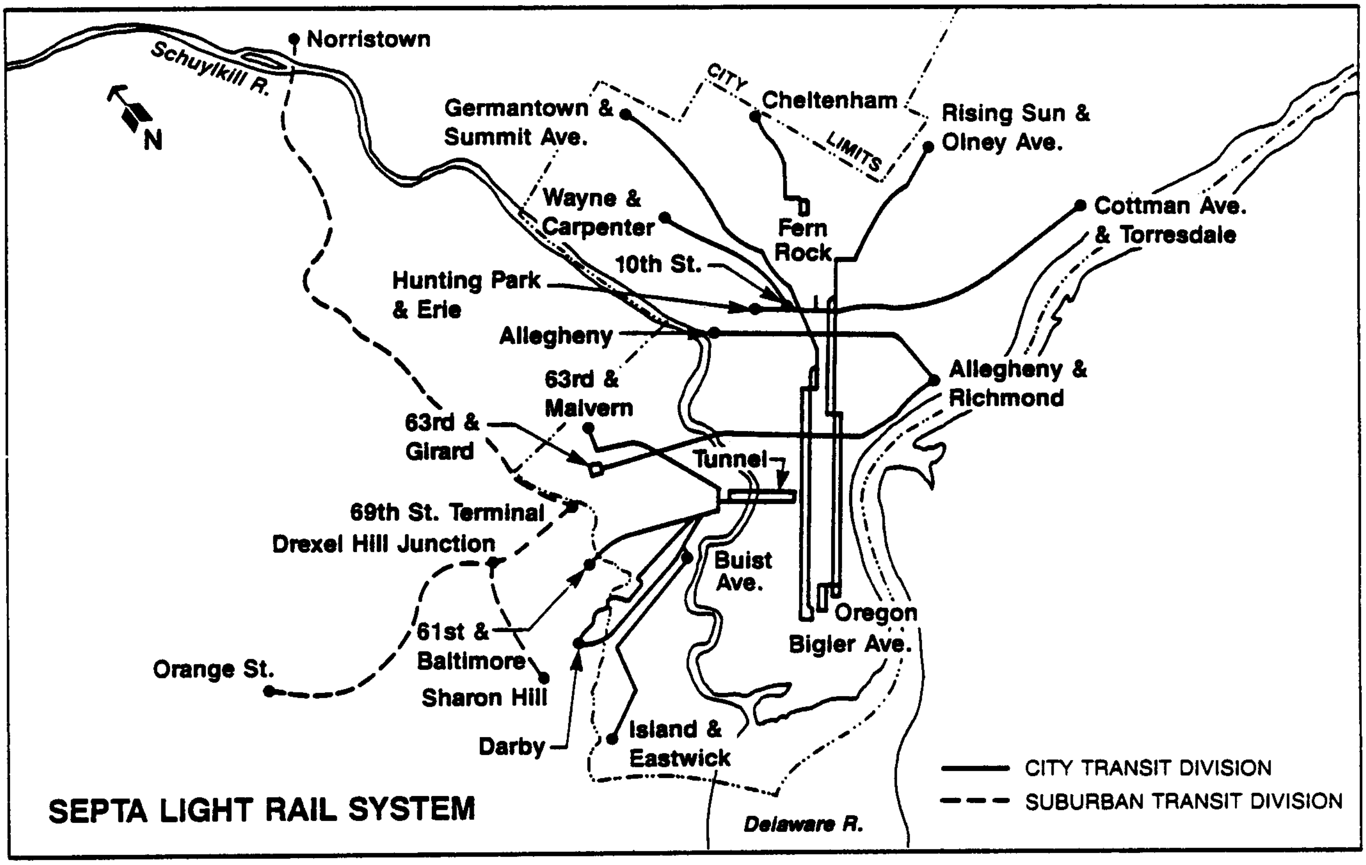
Segment Designation	Segment	Initial Station		Terminal Station	Track Miles
10.11	Montauk/Greenport Branches	Montauk		Babylon	145.9
			and		
		Greenport		Ronkonkoma	
			and		
		Babylon		Bethpage	
10.12	Flatbush Branch	Flatbush		Jamaica	18.0
10.13	Mainline to Penn Station	Jamaica		Penn Station	31.6
10.14	Long Island City Branch	Long Island City		Jamaica	16.3
10.15	Mainline	Floral Park		Hicksville	15.2
10.16	Babylon Branch	Valley Stream		Jamaica (via 2 routes)	26.4



Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
11.1	Hudson Line (elec.)	MP5	Croton-Harmon	120.8
11.2	Hudson Line (diesel)	Croton-Harmon	Poughkeepsie	81.2
11.3	Harlem Line (elec.)	MP5	Brewster North	106.5
11.4	Harlem Line (diesel)	Brewster North	Dover Plains	23.1
11.5	New Haven Line	Woodlawn	New Haven	243.2
11.6	Waterbury Branch	Bridgeport	Waterbury	27.0
11.7	Danbury Branch	S. Norwalk	Danbury	24.0
11.8	New Canaan Branch	Stamford	New Canaan	7.9
11.9	Mott Interlocking	Grand Central Terminal	MP5	20.4



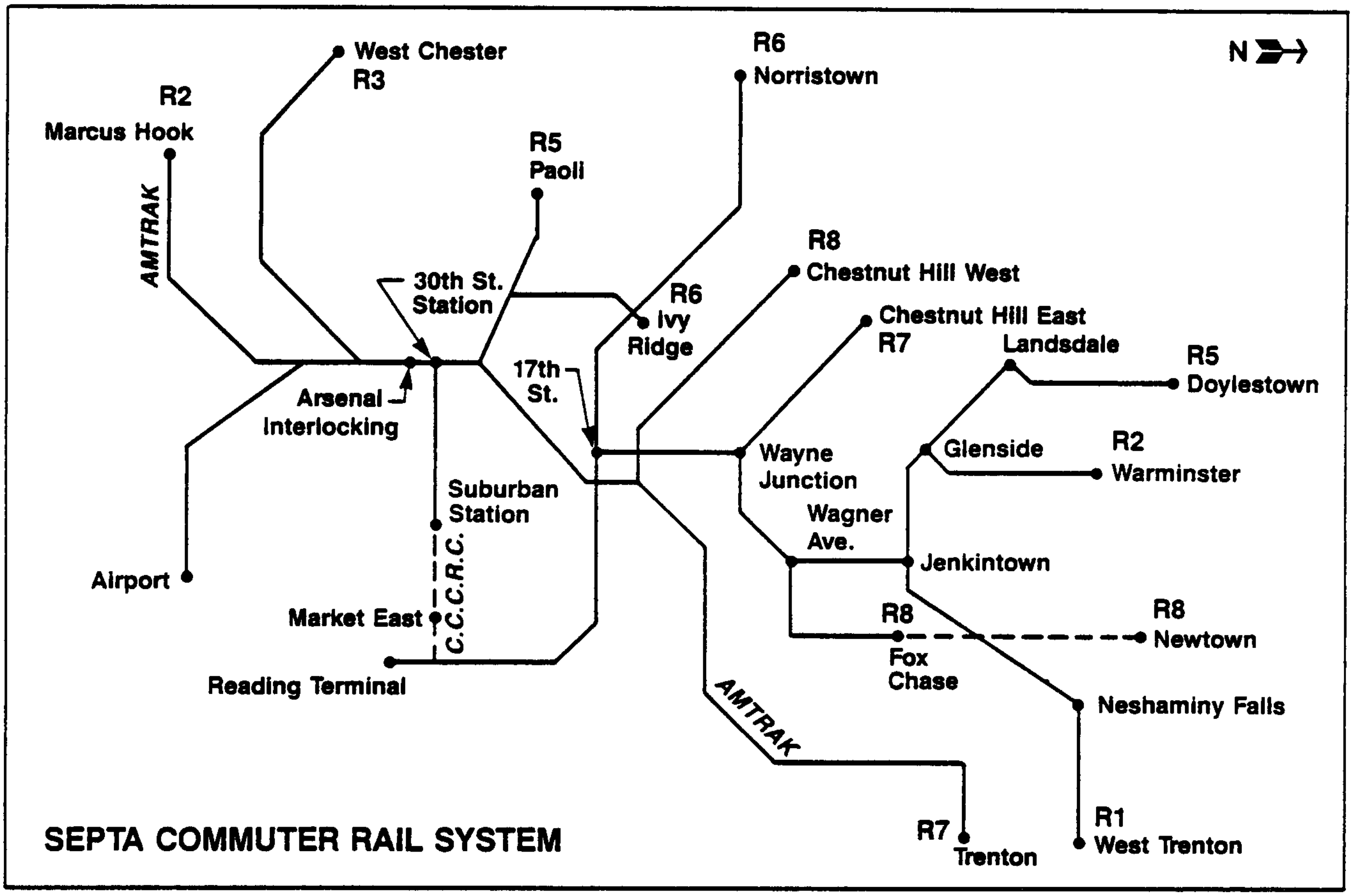
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
13.1	Broad Street North Line	Fern Rock	Walnut-Locust	22.1
13.2	Broad Street South Line	Walnut-Locust	Pattison	6.2
13.3	Market Line	69th St. Terminal	2nd Street	13.7
13.4	Frankford Line	2nd Street	Bridge Pratt	12.6
13.5	Broad-Ridge Spur	8th Street	Erie	2.2



SEPTA LIGHT RAIL SYSTEM

Segment Designation	Segment	Initial Station	Terminal Station	Track Miles
14.1	Media Line	Orange Street	Drexel Hill Junction	12.4
14.2	Sharon Hill Line	Sharon Hill	69th St. Terminal	9.5
14.3	Norristown High Speed Line	Norristown	69th Street	27.6
14.4	North Philadelphia (Surface Routes)			
	Route #15	Allegheny & Richmond	63rd & Girard	16.7
	Route #23	Germantown & Summit Avenue	Bigler Avenue	25.6
	Route #53	Wayne & Carpenter	10th Street	9.0
	Route #56	Erie	Cottman Avenue & Torresdale	14.9

Segment Designation	Segment	Initial Station	Terminal Station	Track Miles
14.5	West Philadelphia (Subway-Surface Lines)			
	Route #10	63rd & Malvern	Tunnel	7.2
	Route #11	Darby	Tunnel @ 40th & Woodland Avenue	7.6
	Route #13	Darby	Tunnel @ 40th & Woodland Avenue	8.5
	Route #34	61st & Baltimore	Tunnel @ 40th & Woodland Avenue	5.2
	Route #36	Island & Eastwick	Buist Avenue	5.8
14.6	Route #10	Tunnel	Center City, Philadelphia	2.5

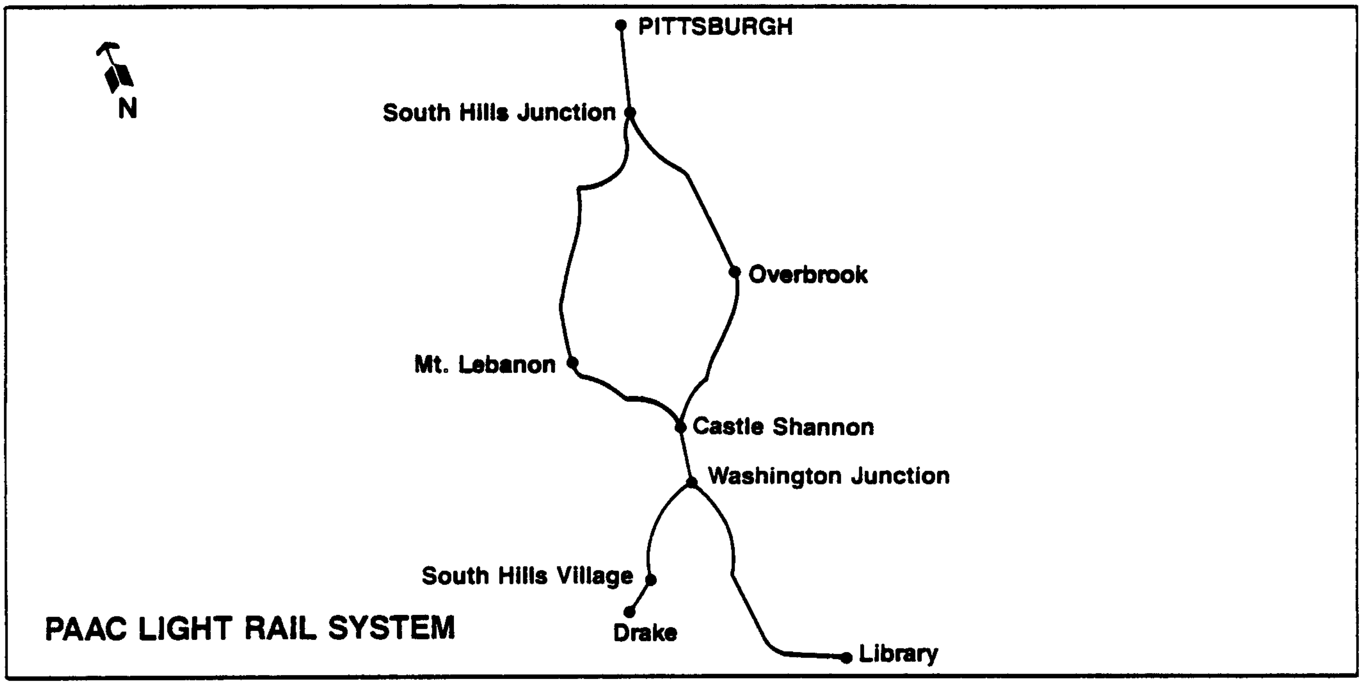


Segment Designation	Segment	Initial Station	Terminal Station	Track Miles
15.1	R-1 (Main)	30th Street Station	Jenkintown	42.1
15.2	R-1 (North)	Jenkintown	Neshaminy Falls	21.0
15.3	R-2	Lansdale Line north-west of Glenside	Warminster	10.6
15.4	R-3	Arsenal Junction	West Chester	41.5
15.5	R-5	West Trenton Line (Jenkintown)	Doylestown	39.2
15.6	R-6	17th Street	Norristown	28.7
		Amtrak Line to Paoli (R5)	Ivy Ridge	5.3
15.7	R-7	Wayne Junction	Chestnut Hill East	11.4

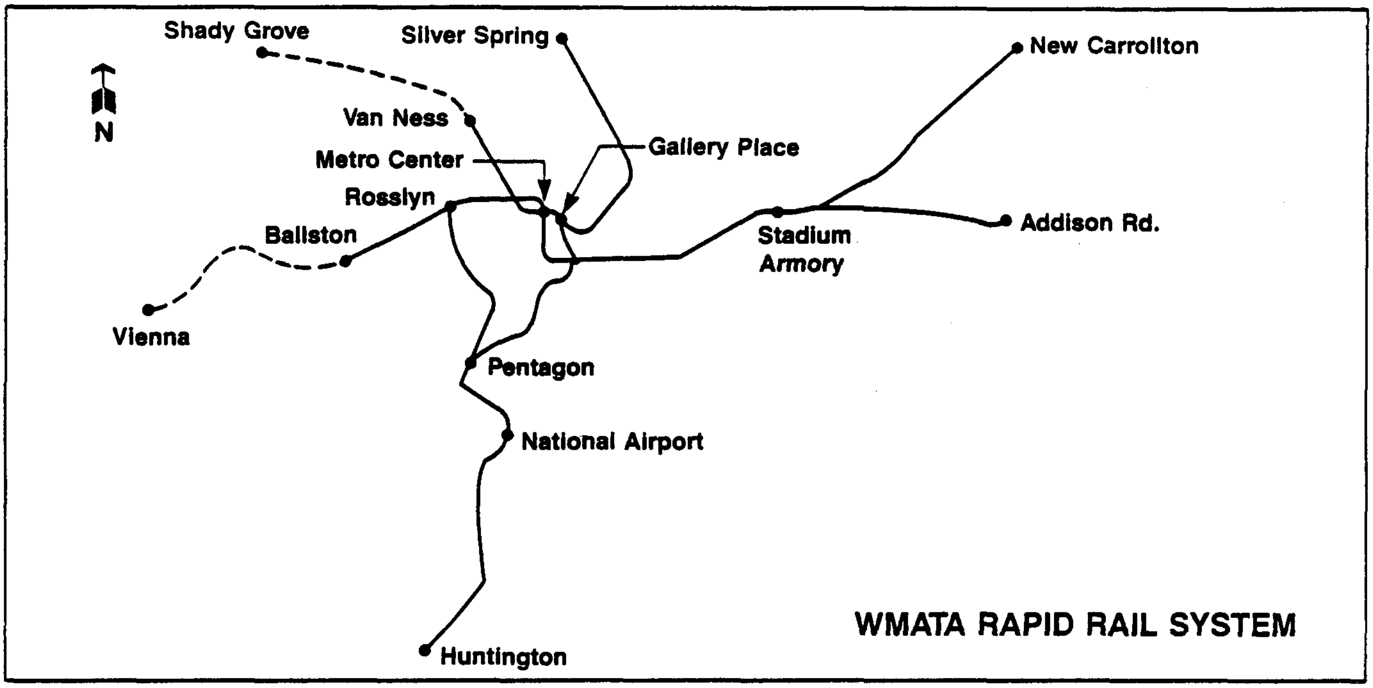
Segment Designation	Segment	Initial Station	Terminal Station	Track Miles
15.8	R-8	Amtrak Mainline	Chestnut Hill West	13.4
		Fox Chase	Newtown	16.9
15.9	Airport	Amtrak Mainline (near Arsenal)	Airport	8.0

NOTE: The following segments are operated by Amtrak or Conrail. SEPTA is responsible only for the stations.

15.10	R-1 (East)	Neshaminy Falls	West Trenton	22.8
15.11	R-2 (South)	Junction w/R3 Line	Marcus Hook	31.2
15.12	R-5 (Paoli)	Junction w/Amtrak Mainline	Paoli	38.0
15.13	R-7 (East)	30th Street	Trenton	66.6
15.14	R-8 (South)	Wagner Ave. (R1)	Fox Chase	5.5

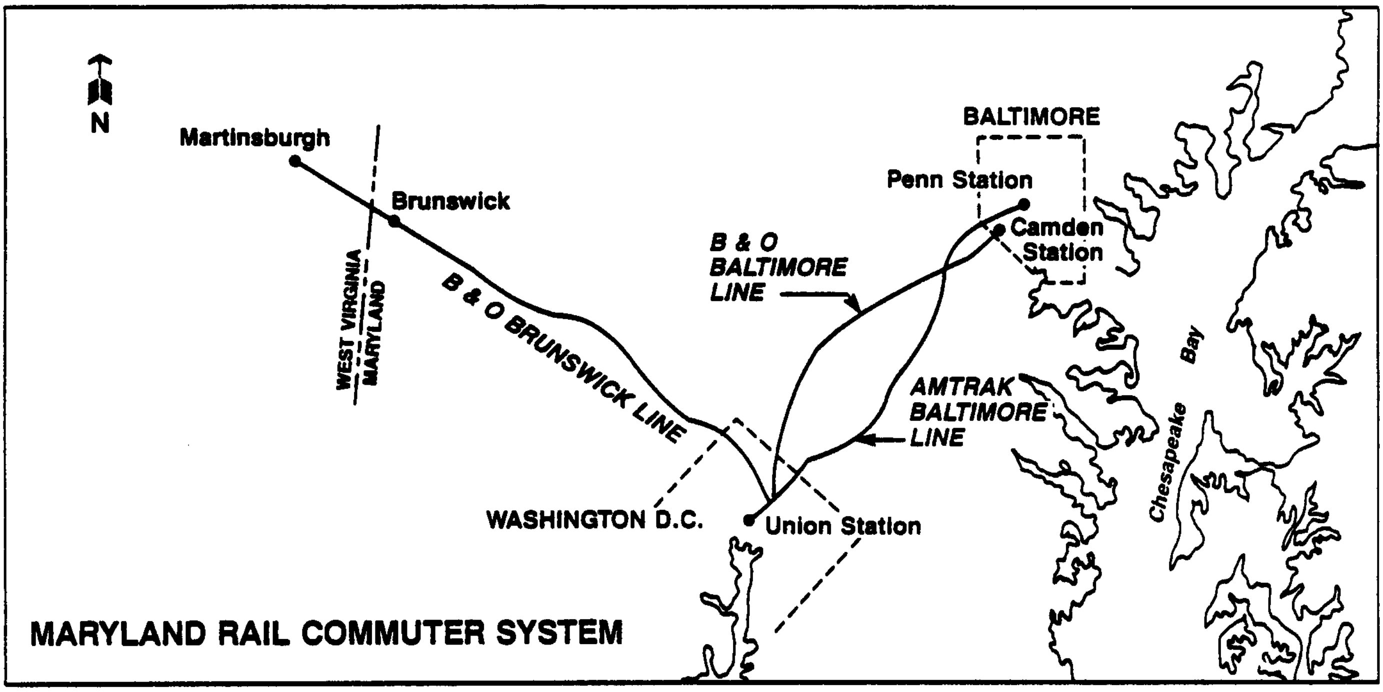


Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
16.1	Overbrook Trolley Line	South Hills Junction	Castle Shannon	14.1
16.2	Library Trolley Line	Washington Junction	Library	8.4
16.3	Drake Trolley Line	South Hills Village	Drake	1.5



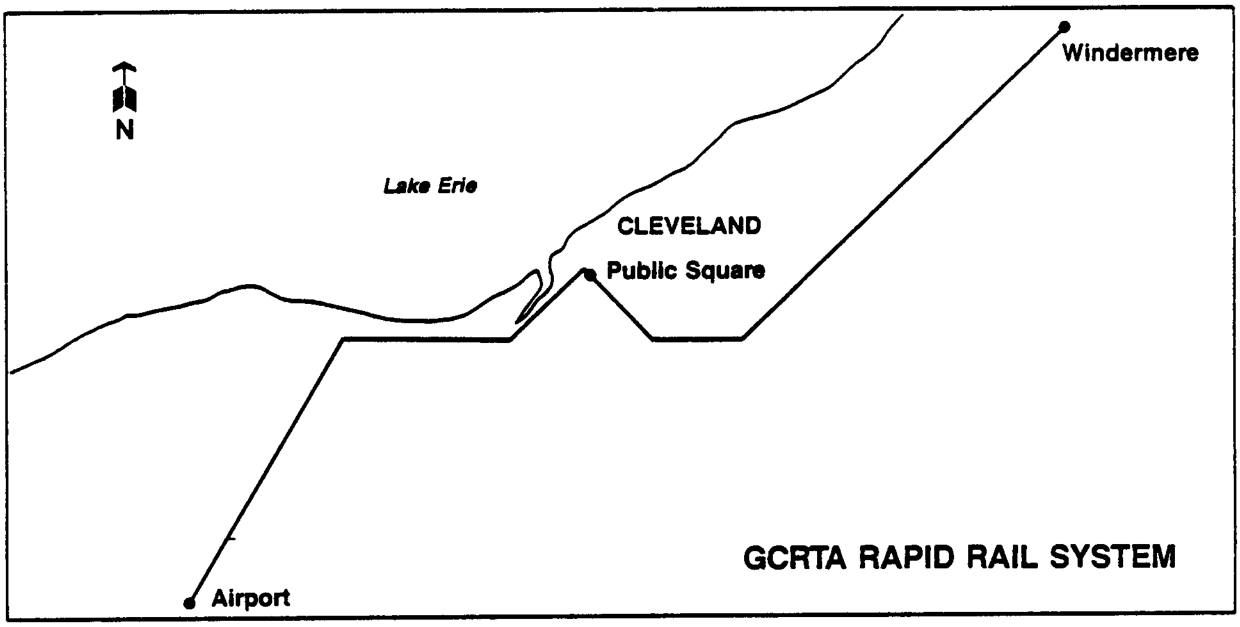
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
17.1	Red Line	Van Ness - UDC	Silver Spring	26.72
		Van Ness - UDC	Shady Grove*	
		Vienna	Ballston*	
17.2	Orange Line	Ballston	Rosslyn	5.70
		Metro Center	New Carrollton	23.04
17.3	Blue Line	Junction East of Stadium Armory	Addison Road	7.69
		Metro Center	Huntington	24.20
17.4	Yellow Line	Gallery Place	Pentagon	10.55

*Not completed at time of inspections.

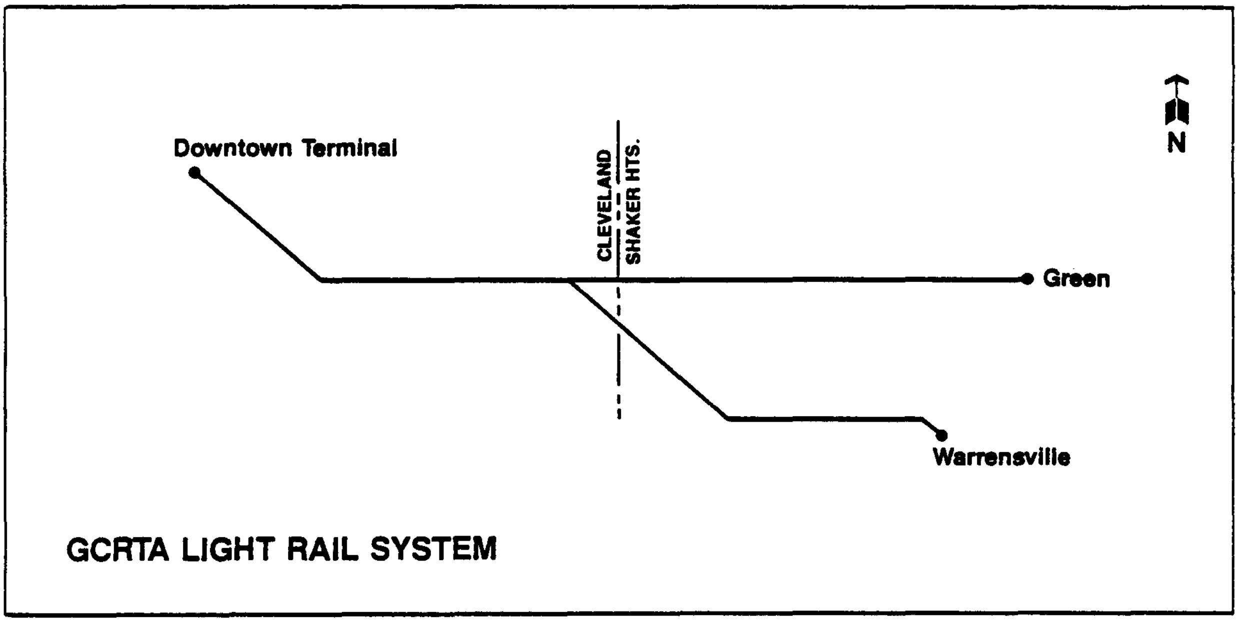


Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
18.1	Amtrak Baltimore Line	Penn Station	Union Station	80.0*
18.2	B&O Baltimore Line	Camden Station	Union Station	41.0*
18.3	B&O Brunswick Line	Martinsburg	Union Station	72.0*

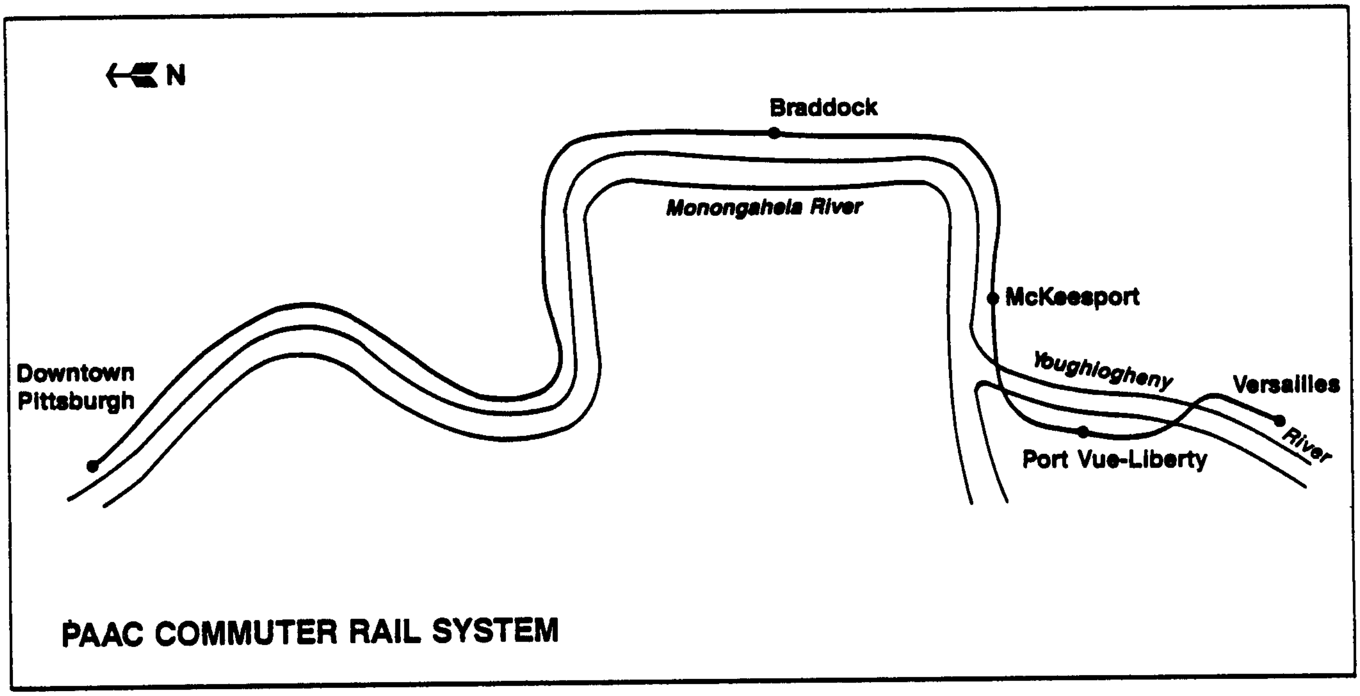
*Vehicles and stations are the only elements that apply for this system.



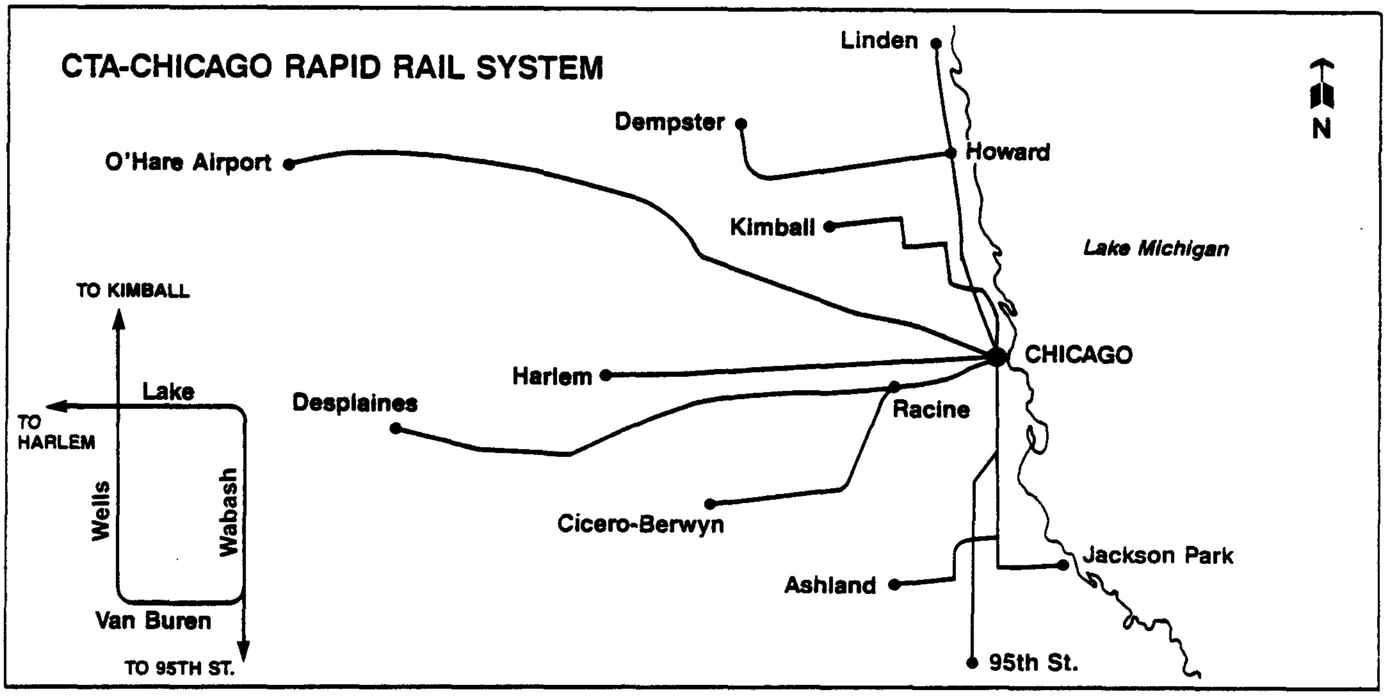
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
20.1	Red Line South	Airport	Public Square	23.6
20.2	Red Line North	Public Square	Windermere	15.2



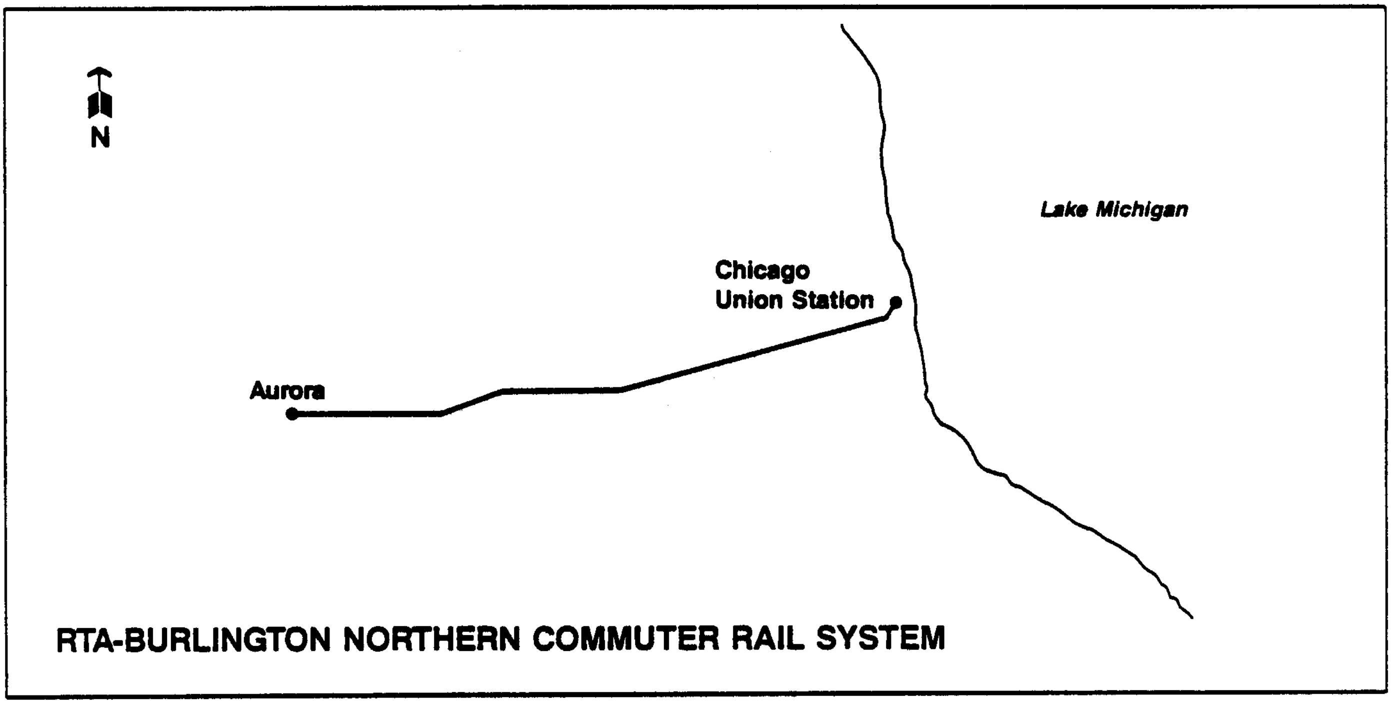
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
21.1	Green & Blue Lines	Green	East 55th Street	20.4
		Warrensville	Shaker Square	



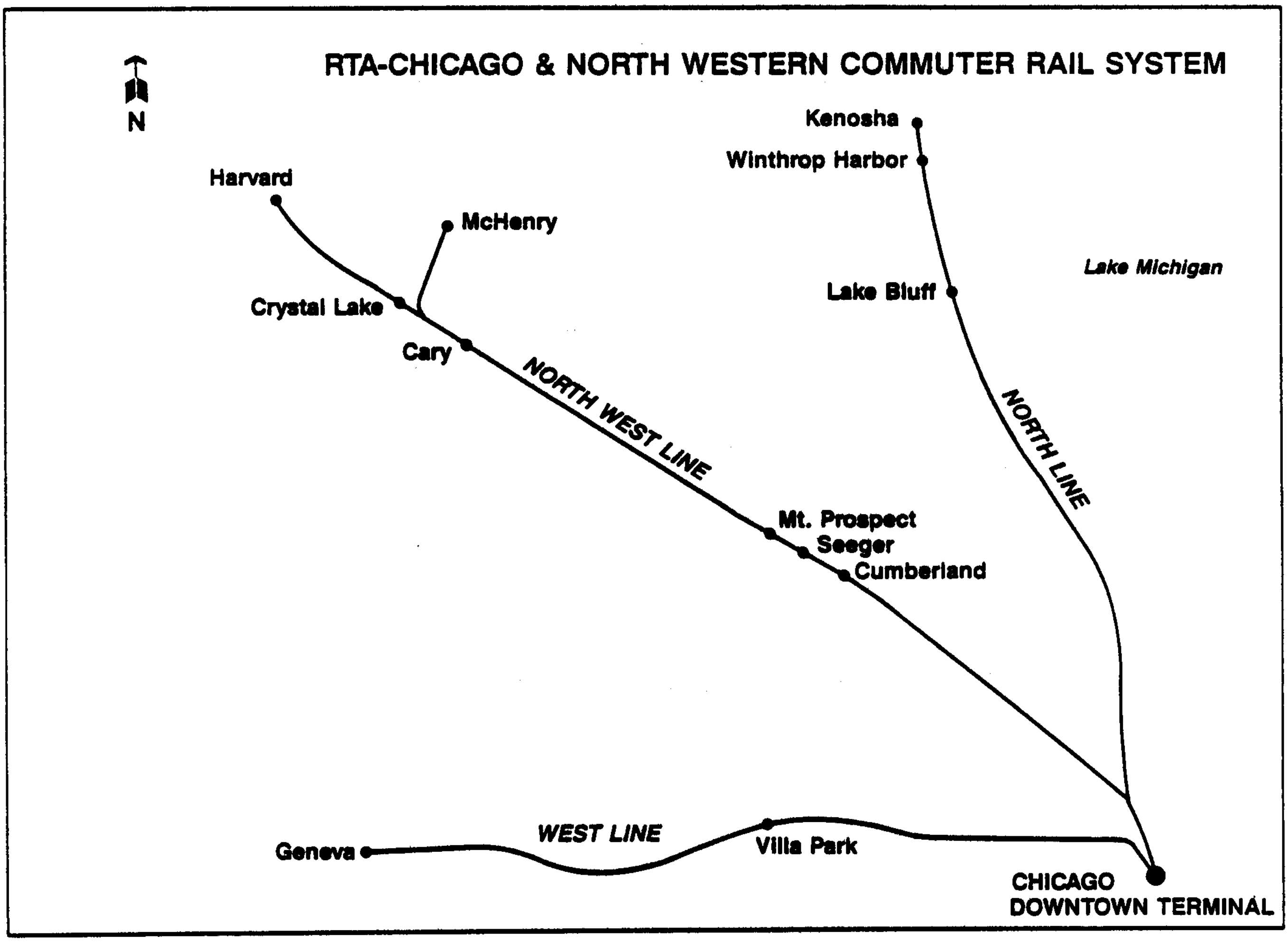
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
22.1	PAAC Commuter Rail Line	Downtown Pittsburgh	Versailles	57.0



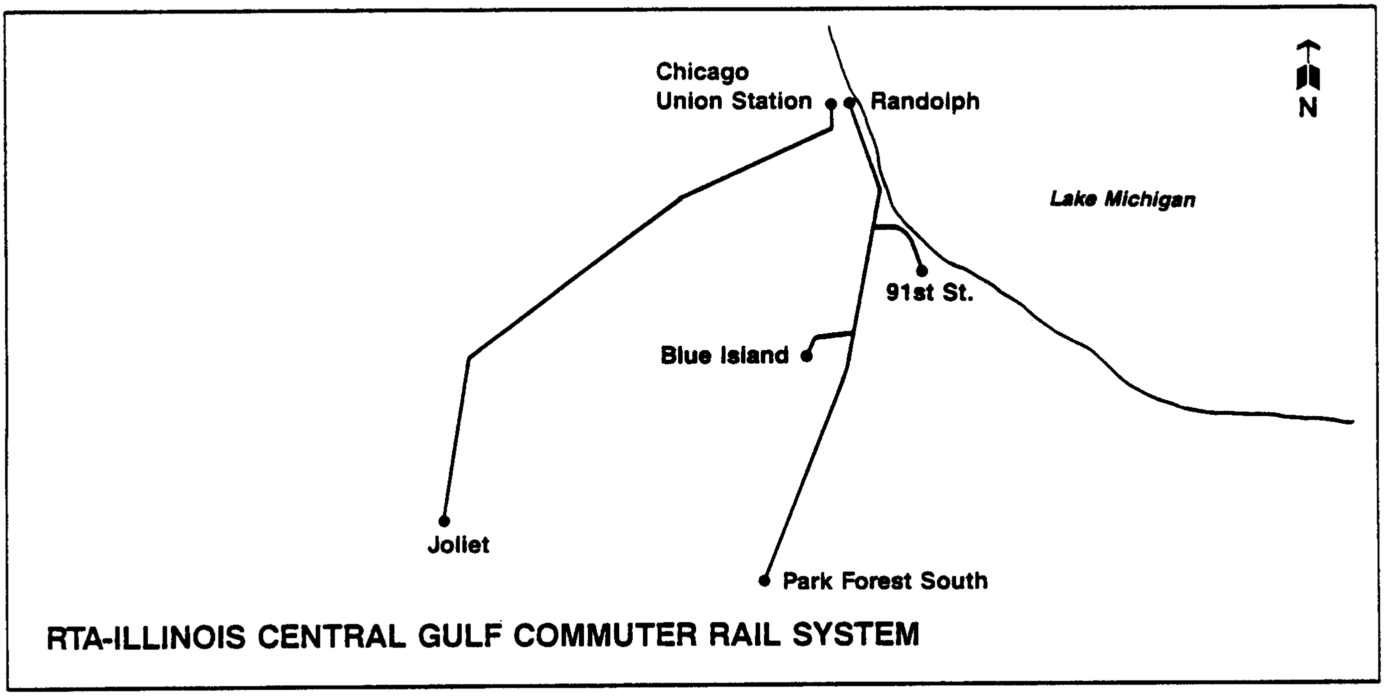
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
23.1	Downtown Loop	Over Wabash, Lake, Wells & Van Buren Streets		4.10
23.2	North-South Mainline	Howard	Ashland & Jackson Park	62.06
23.3	West-Northwest Mainline	O-Hare Airport	Desplaines	64.00
		Racine	Cicero-Berwyn	13.50
23.4	West-South Mainline	95th Street Station	Southeast Corner of the Loop	23.70
		Northwest Corner of the Loop	Harlem	20.90
23.5	Ravenswood Line	Northwest Corner of the Loop	Kimball	16.30
23.6	Evanston Line	Linden	Howard	8.30
23.7	Skokie Swift Line	Dempster	Howard	10.00



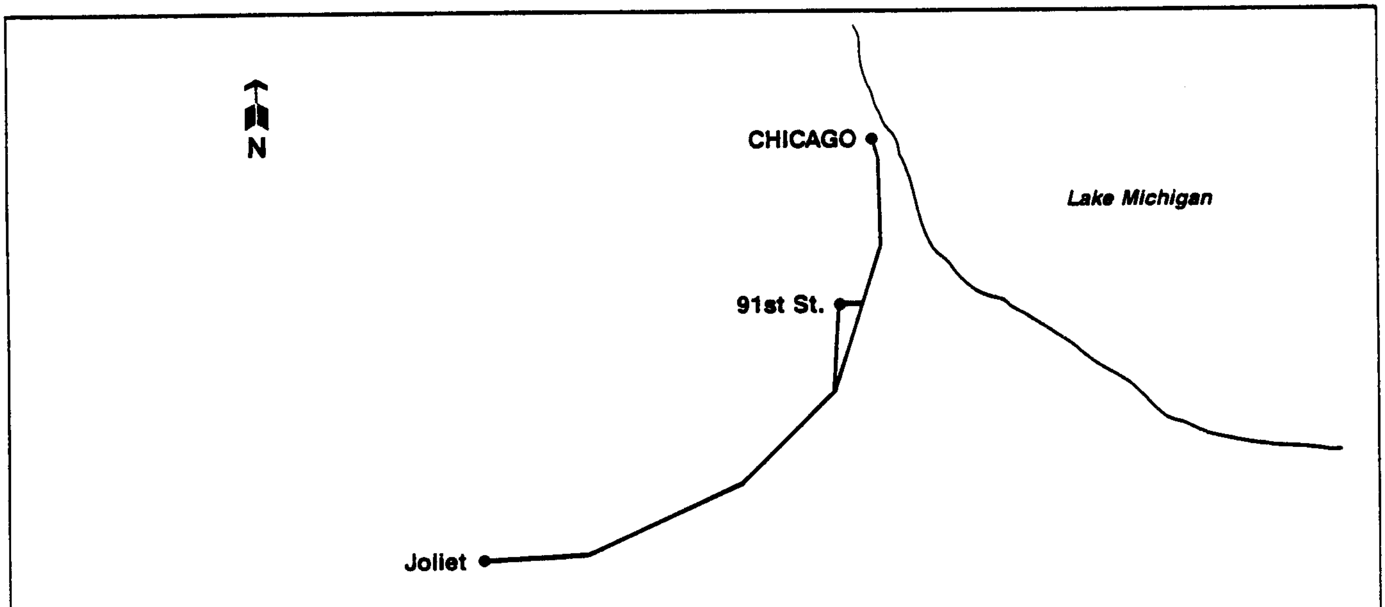
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
24.1	RTA Burlington Northern	Aurora	Chicago Union Station	111.4



Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
25.1	North Line	Chicago Downtown Terminal	Kenosha, Wisconsin	120.5
25.2	Northwest Line	Chicago Downtown Terminal	Harvard	179.0
25.3	West Line	Chicago Downtown Terminal	Geneva	103.0

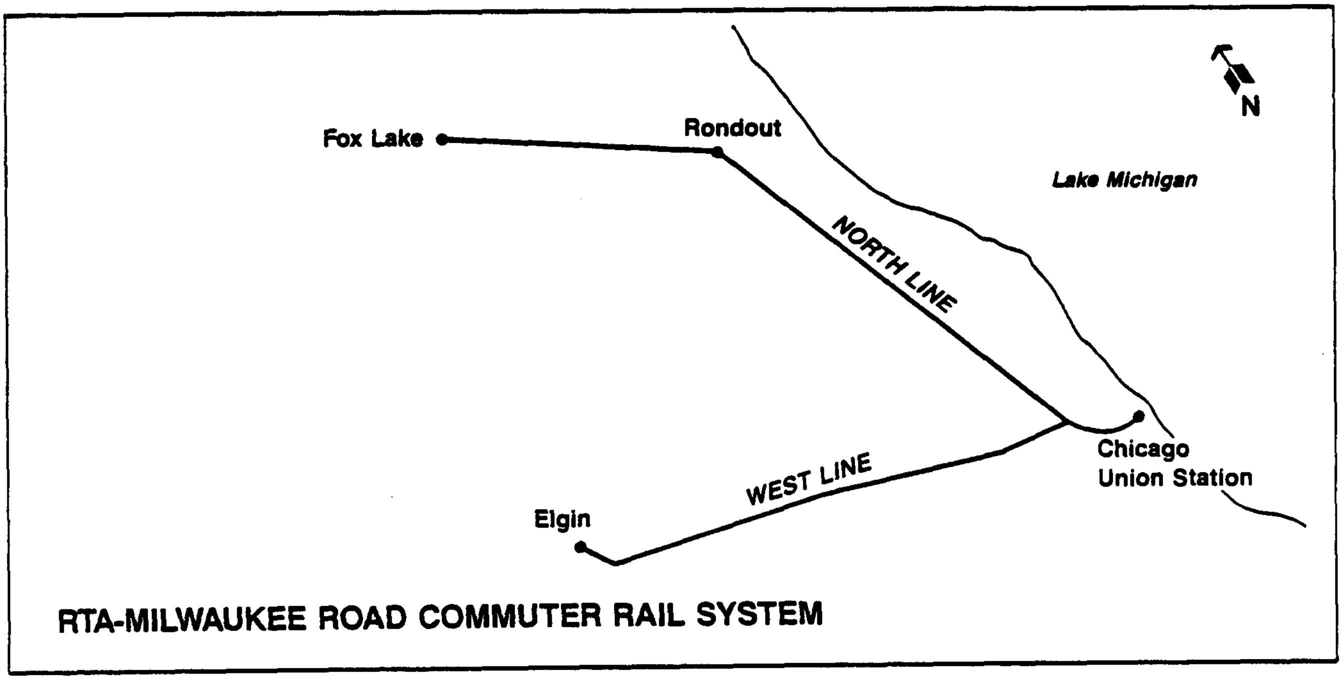


Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
26.1	South Mainline	Randolph	Park Forest South	88.31
26.2	South Chicago Branch	Mainline between 67th & 75th St.	91st Street	8.47
26.3	Blue Island Branch	Mainline between 115th St. & Riverdale	Blue Island	3.25
26.4	Joliet Line	Chicago Union Station	Joliet	83.87

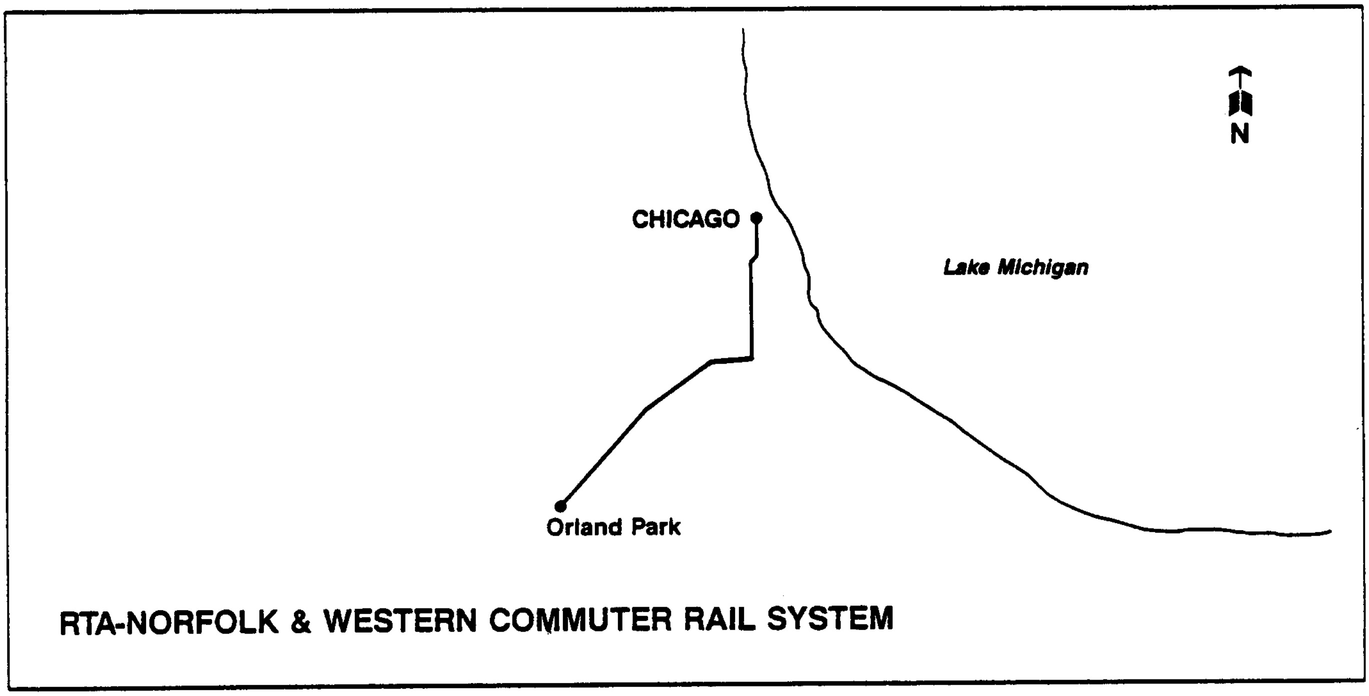


RTA-ROCK ISLAND LINES COMMUTER RAIL SYSTEM

Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
27.1	Rock Island/South Line	Joliet	Chicago	100.0

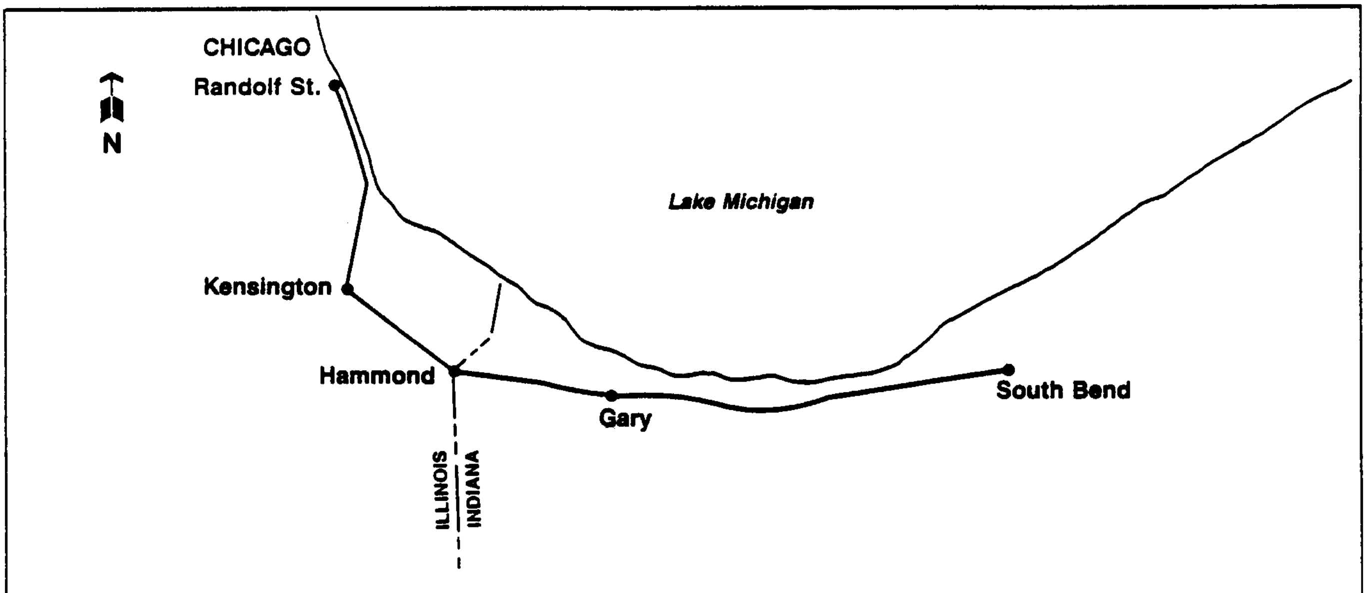


Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
28.1	North Line	Fox Lake	Chicago Union Station	91.19
28.2	West Line	Elgin	Tower A-5 on the North Line	67.75



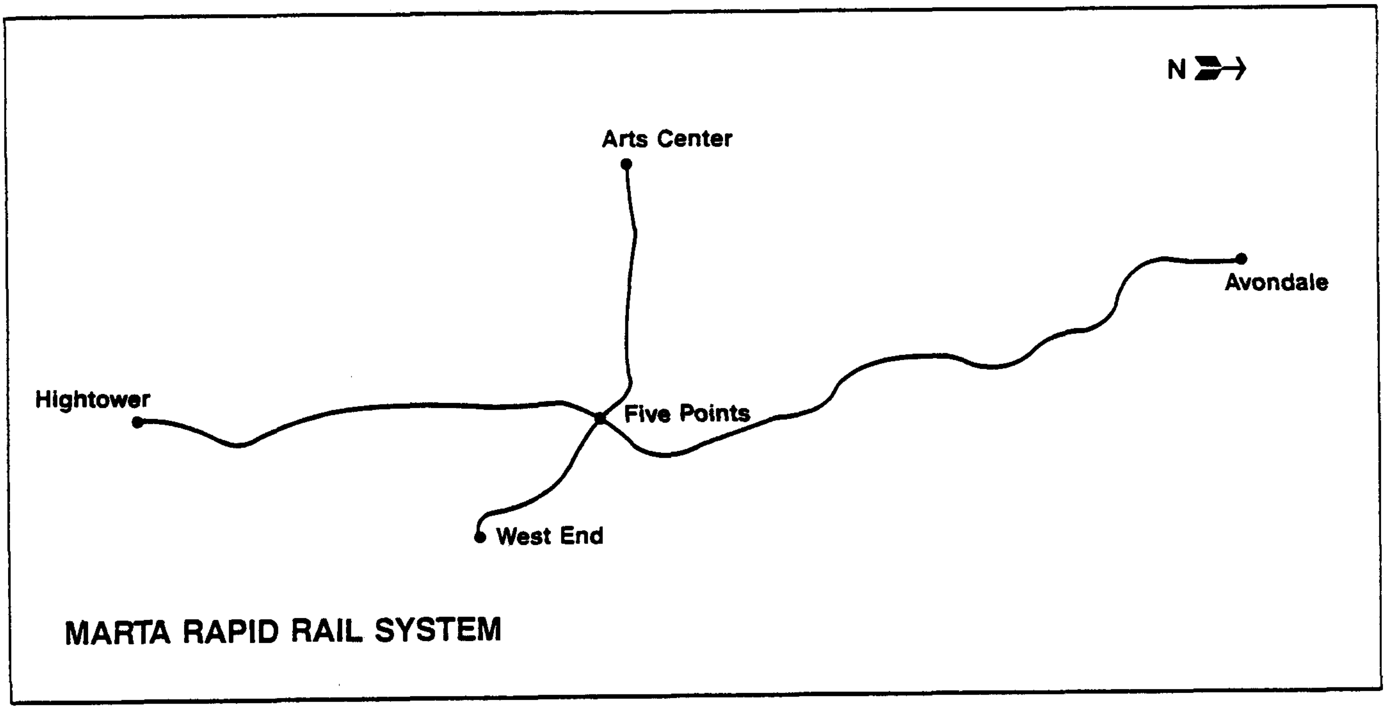
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
29.1	N&W/Orland Park Line	Chicago	Orland Park	23.5*

*Track not the responsibility of Norfolk & Western.

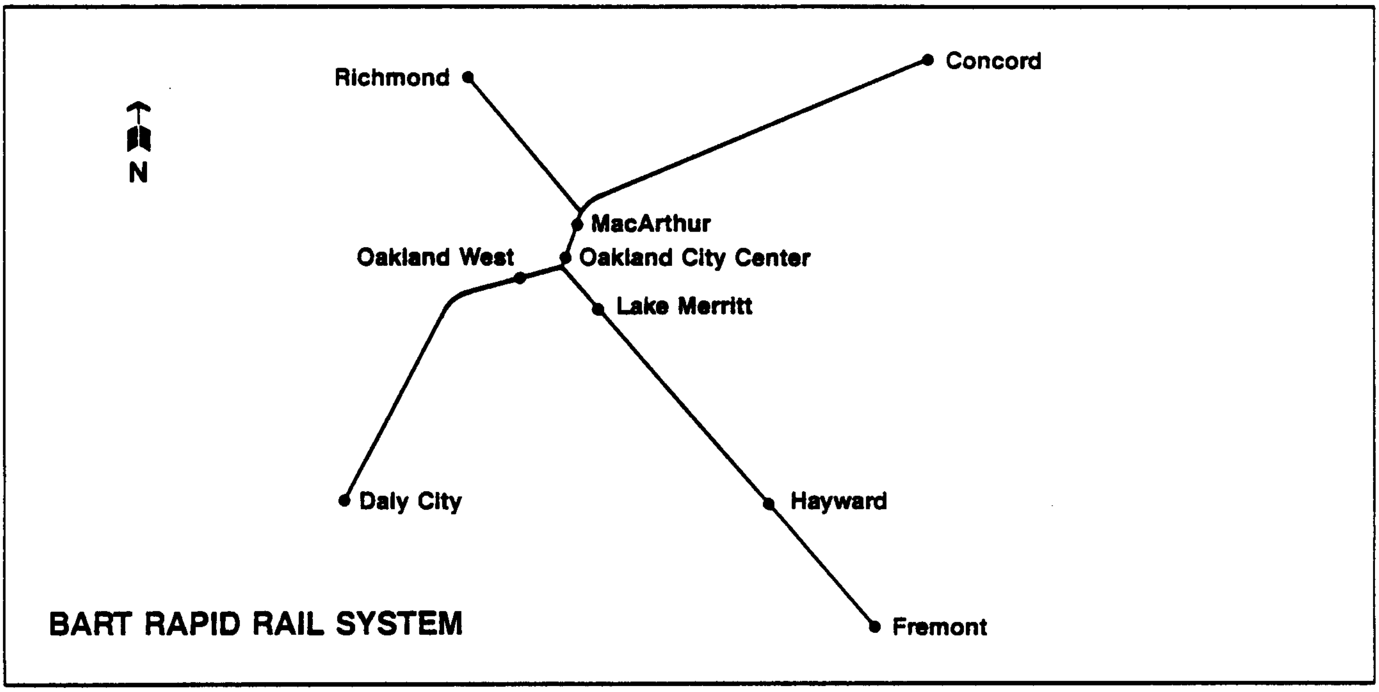


RTA-NICTD: CHICAGO, SOUTH SHORE & SOUTH BEND COMMUTER RAIL SYSTEM

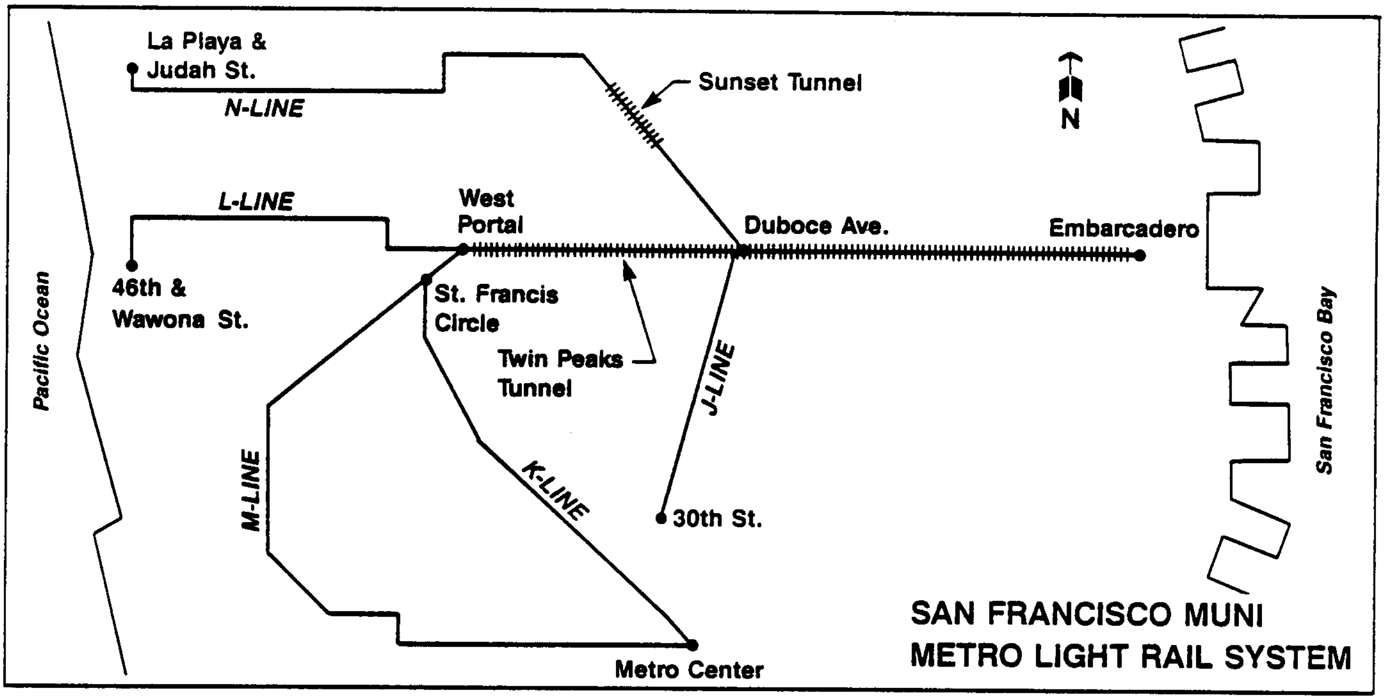
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
30.1	Chicago South Shore & South Bend Line	Randolf Street	South Bend	91.3



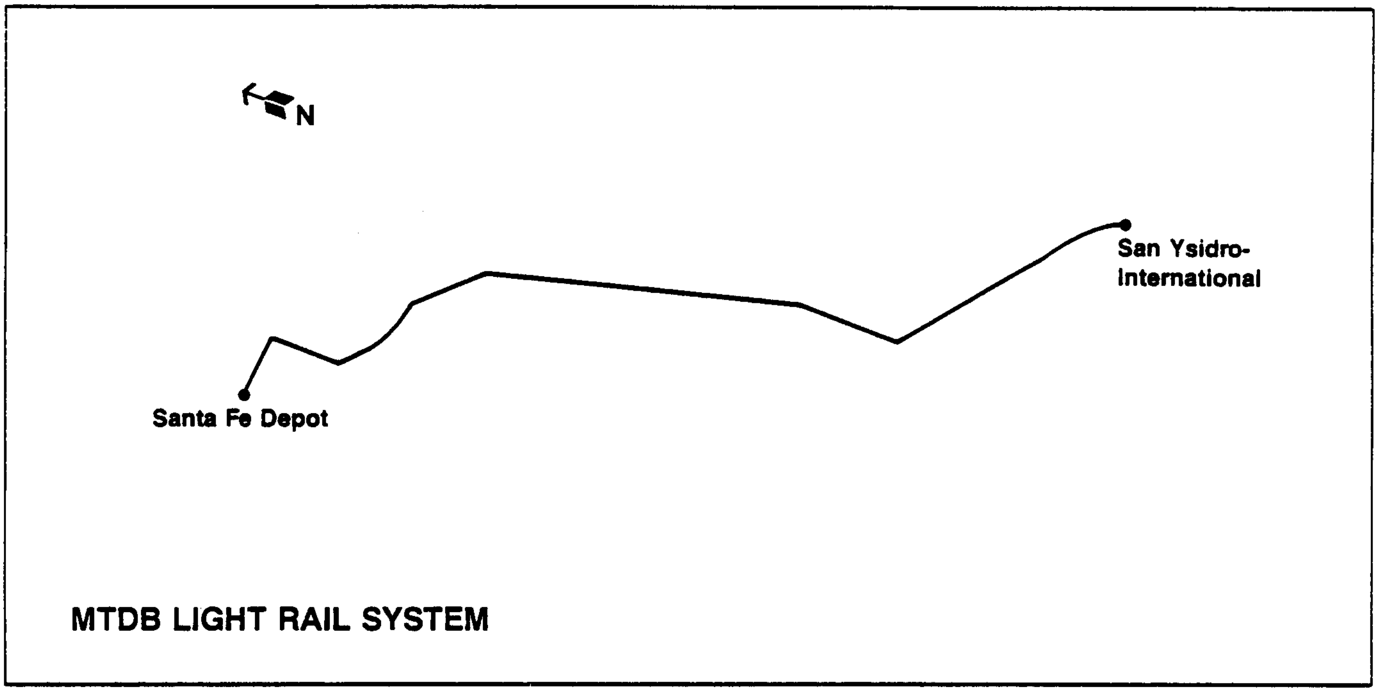
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
31.1	North Line	Five Points	Arts Center	6.0
31.2	East Line	Five Points	Avondale	14.6
31.3	South Line	Five Points	West End	4.4
31.4	West Line	Five Points	Hightower	10.2



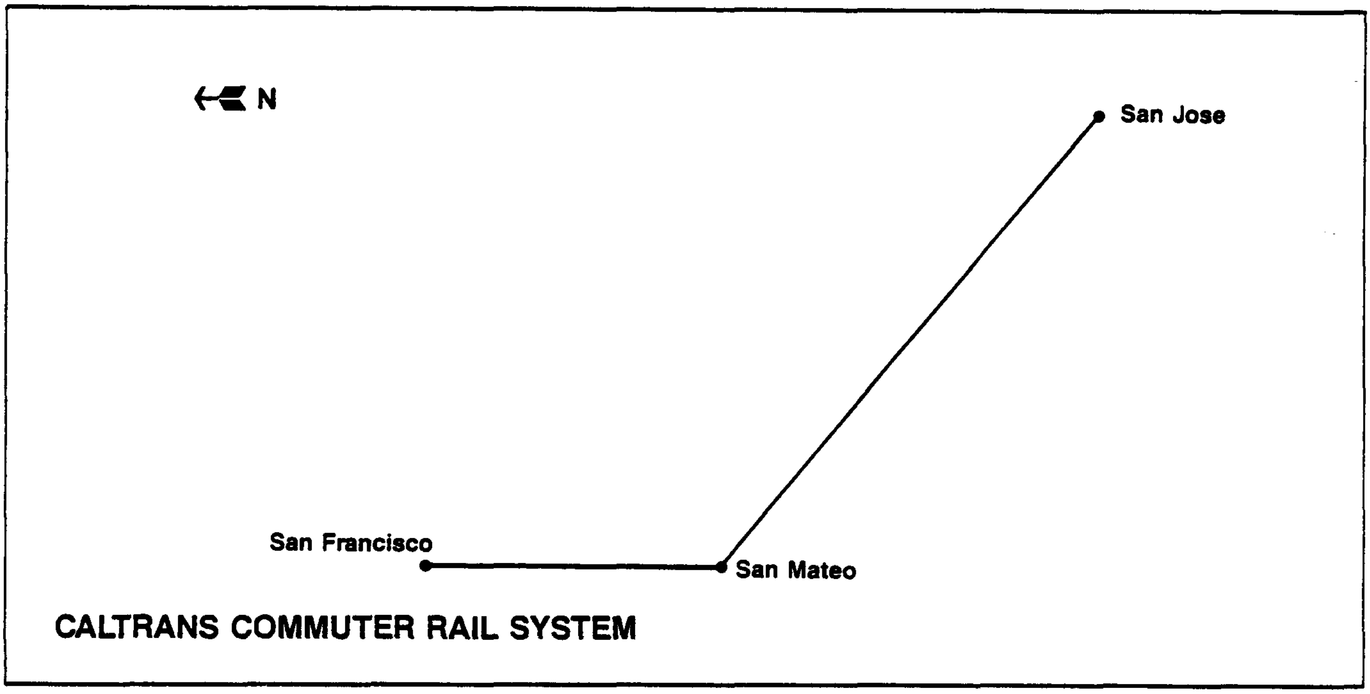
Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
32.1	A Line	Fremont	Lake Merritt	47.2
32.2	C Line	Concord	MacArthur	36.3
32.3	K Line	Oakland Wye - underground, shared tracks between MacArthur Station, Lake Merritt Station, and Oakland West Station		10.0
32.4	M Line	Daly City	Oakland West	32.0
32.5	R Line	Richmond	MacArthur	22.7



Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
33.1	J Line	30th Street	Duboce Avenue	3.7
33.2	K Line	Metro Center	St. Francis Circle	4.1
33.3	L Line	46th & Wawona St. Terminal	West Portal	5.7
33.4	L Line (Subway)	West Portal	Embarcadero	10.4
33.5	M Line	Metro Center	West Portal	7.8
33.6	N Line	La Playa & Judah St. Terminal	Intersection with MUNI Metro Subway @ Duboce Avenue & Market Street	9.1

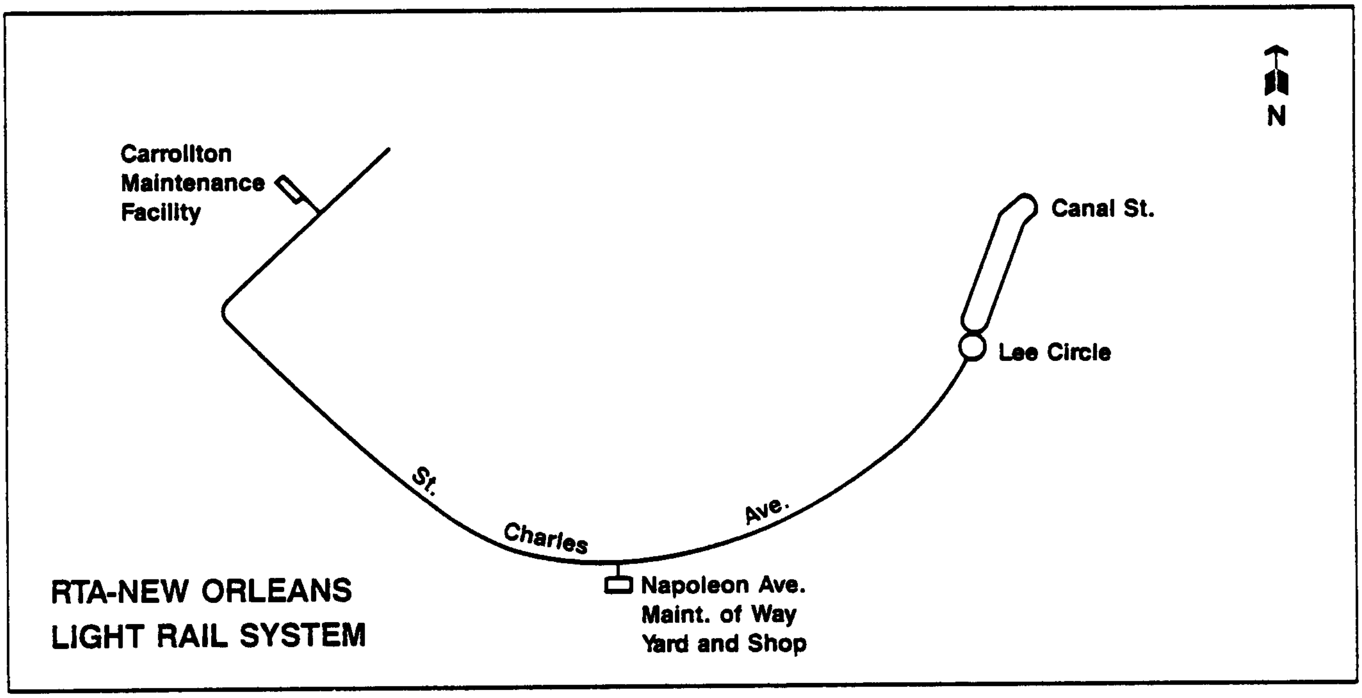


Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
34.1	San Diego Trolley Line	Santa Fe Depot	San Ysidro (Int'l Border w/Mexico)	31.8



Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
35.1	Southern Pacific Line	San Francisco	San Jose	93.8*

*Track not the responsibility of CALTRANS.



Segment Designation	Segment	Initial Point	Terminal Point	Track Miles
36.1	St. Charles Streetcar Line	Canal Street	S. Claiborne Avenue	13.5

5.4 TRANSIT SYSTEM UTILIZATION

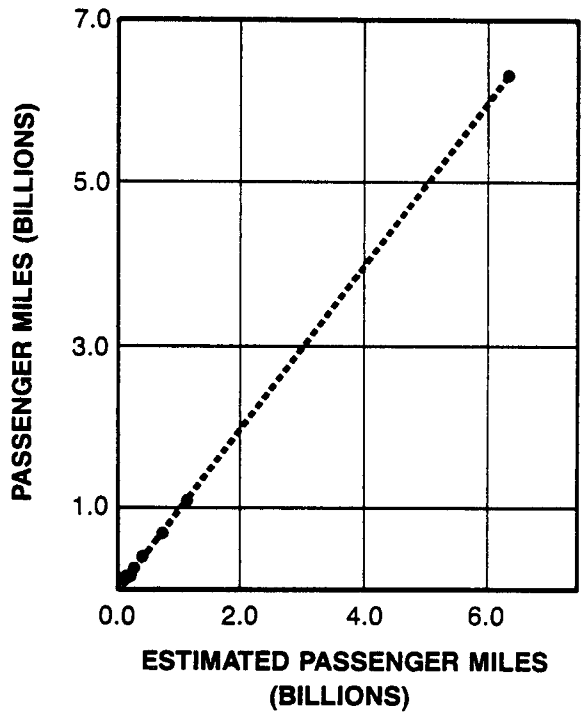
The transit system utilization on each of the previously described segments was estimated by developing a simple linear regression formula. The independent variables in this formula included the track miles, number of stations, and station utilization, which were all obtained during the physical inspection of each transit system.

The passenger miles on each transit system were obtained from the 1983 Section 15 Annual Report on National Urban Mass Transportation Statistics or from the individual transit operators. These passenger mile estimates are summarized in Table 5.4 and the percentage by type and of the total are also provided.

Numerous regression analyses were performed and evaluated in order to obtain the highest possible correlation coefficients for each type of transit system. After this correlation was acquired, the resulting formulas were used to estimate the passenger miles on each segment of each type of transit system. A discussion of this analysis and the resulting correlation between the estimates is provided in the following paragraphs.

- Rapid Rail. The rapid rail systems were assumed to be able to provide the best estimate of passenger miles since many of them have automated fare collection systems that can be used to provide accurate data on station-to-station travel. The regression analysis provided a correlation of 99.8 percent between the operator provided estimates and the estimates obtained from the regression formulas. The results are indicated in Figure 5.1 and it can be observed that there is little difference between the estimated passenger miles (obtained from the formula) and the actual passenger miles (provided by the transit operators). However, two formulas were still necessary to provide the highest possible correlation between estimated and actual values because of the wide variation in total passenger miles. (Note: The data in Table 5.4 indicates that NYCTA and CTA have relatively high passenger mile estimates and a separate formula was used for these two transit systems.)

FIGURE 5.1
PASSENGER MILE ESTIMATION FOR RAPID RAIL SYSTEMS



- Light Rail. The light rail systems in the United States utilize various types of fare collection systems, with most using a constant or zonal fare. Therefore, it is more difficult for the Transit Authority to estimate station-to-station travel

TABLE 5.4

Passenger Mile Estimates
(Millions)

Rapid Rail		Percent of Type	Percent of Total
PATCO	92.8	.9	.6
MBTA	393.5	3.9	2.4
NYCTA	6,330.8	62.8	39.2
SIRTOA	27.2	.3	.2
PATH	260.3	2.6	1.6
SEPTA	540.3	5.4	3.3
WMATA	413.1	4.1	2.6
GCRTA	69.9	.7	.4
CTA	1,093.2	10.8	6.8
MARTA	131.4	1.3	.8
BART	725.1	7.2	4.5
Subtotal	10,077.6	100.0	62.5
Light Rail			
MBTA	30.4	7.8	.2
NJTC	6.3	1.6	0
SEPTA	108.1	27.7	.7
PAAC	18.5	4.7	.1
GCRTA	37.2	9.5	.2
MUNI	138.1	35.4	.9
MTDB	35.1	9.0	.2
NEW ORLEANS RTA	16.8	4.3	.1
Subtotal	390.5	100.0	2.4
Commuter Rail			
NJTC	795.2	14.0	4.9
MBTA	195.5	3.5	1.2
LIRR	2,042.0	36.1	12.7
METRO NORTH	1,133.3	20.0	7.0
SEPTA	183.7	3.2	1.1
MARC	9.9	.2	.1
PAAC	5.1	.1	0
BN	216.1	3.8	1.3
C&NW	464.0	8.2	2.9
ICG	204.6	3.6	1.3
RI	98.3	1.7	.6
MIL RD	174.5	3.1	1.1
N&W	1.5	0	0
SS&SB	62.0	1.1	.4
CALTRANS	75.0	1.3	.5
Subtotal	5,660.7	100.0	35.1
TOTAL	16,128.8		

and thus passenger miles. As a result, it was necessary to conduct a more comprehensive analysis of the passenger mile estimates in order to obtain the highest possible correlation between estimates. The results are provided in Figure 5.2 and it can be observed that there are some minor differences between the passenger miles estimates by the formulas and the actual or estimates provided by the Transit Operators. As a result, it was necessary to normalize all passenger mile estimates on the different segments so that the final total estimates agreed with those provided by the transit operators.

o Commuter Rail. The commuter rail systems in the United States also utilize various types of non-automated fare collection systems and therefore it is difficult for the transit operators to determine station-to-station travel and thus passenger miles. As a result, it was necessary to conduct a reasonable comprehensive analysis of the results obtained from the regression analysis in order to obtain the best possible correlation between the estimates obtained from the formulas and the estimates obtained from the transit operators. The results of this analysis are provided in Figure 5.3 and a correlation of between 97

FIGURE 5.2

PASSENGER MILE ESTIMATION FOR LIGHT RAIL SYSTEMS

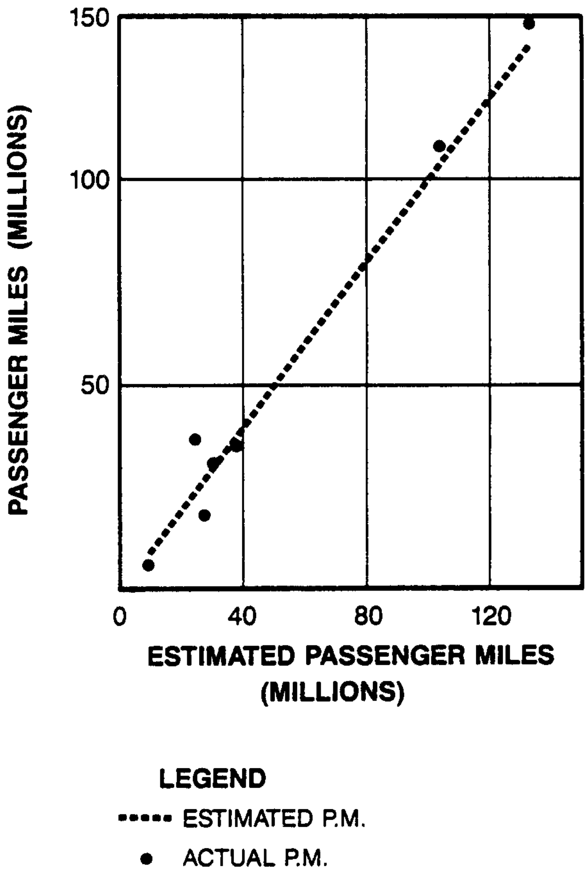
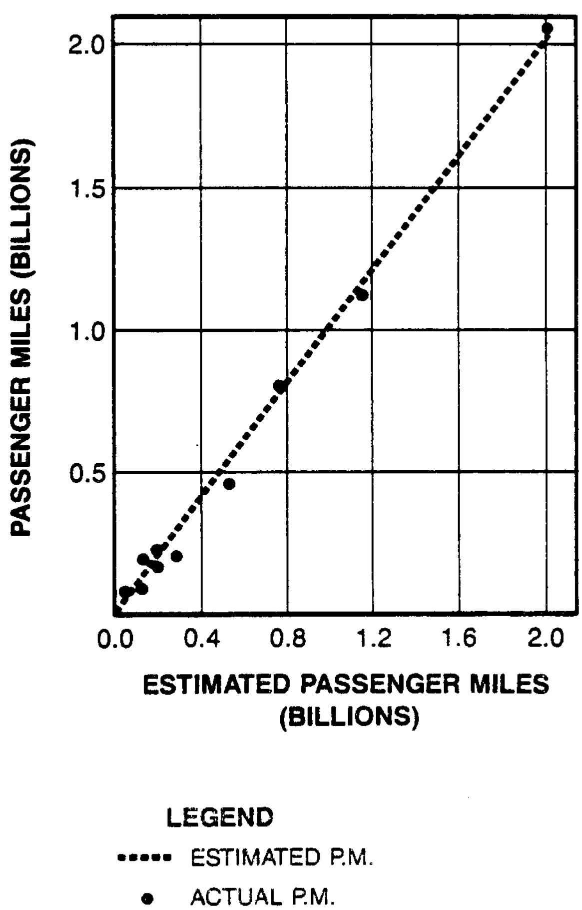


FIGURE 5.3

PASSENGER MILE ESTIMATION FOR COMMUTER RAIL SYSTEMS



percent and 99 percent was obtained. However, two regression formulas were required to provide the reasonably high correlation illustrated in Figure 5.3; the estimates for each segment were also normalized so that the total passenger mile estimates for each transit system agreed with those provided by the transit operator.

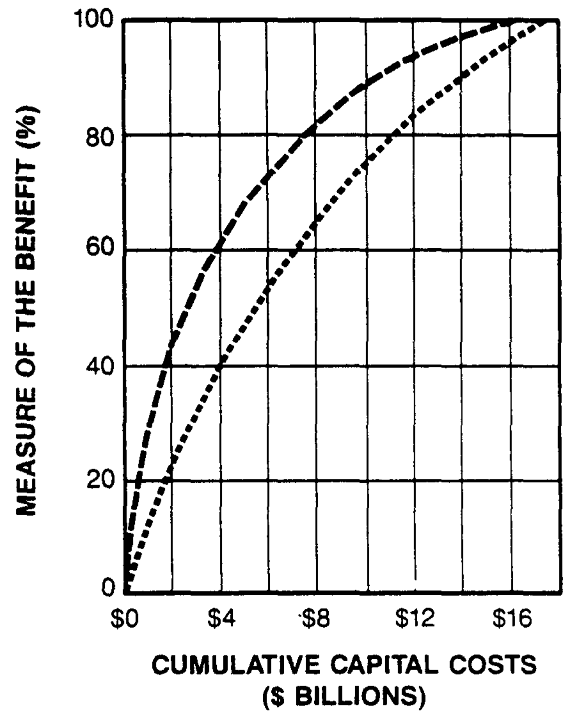
5.5 TRANSIT SYSTEM BENEFITS AND CAPITAL COSTS

The cost effectiveness of proposed improvements to the different segments was determined by using each of the two methods described in Section 5.2. The benefit/cost ratios for each project in each segment were calculated and a summary of the benefit/cost ratios for each of the 186 segments was determined. The transit system segments were then arranged in the order of their benefit/cost ratios with the highest ratios first and the lowest ratios last.

A summary of the results, using both methods, is provided in Figure 5.4.

Of particular interest is the percentage of the total benefit that is achieved for various levels of capital funding and the differences in using the two different methods. For example, in order to achieve 80 percent of the benefits, capital funding of between $7.7 billion and $11.3 billion would be required. At the 90 percent benefit level, between $10.9 billion and $14.0 billion in funding would be required, depending upon the method of estimating benefits. Of particular interest is that when the passenger mile versus capital cost method is used, 80 of the 186 segments (43 percent) would not have to be improved in order to still obtain 90 percent of the benefits. With the LTI method of estimating benefits, more than 50 of the 186 segments (27 percent) would not have to be improved in order to obtain 90 percent of the benefits.

FIGURE 5.4
TOTAL BENEFITS VS. TOTAL CAPITAL COSTS FOR FULL REHABILITATION (ALL SYSTEMS)



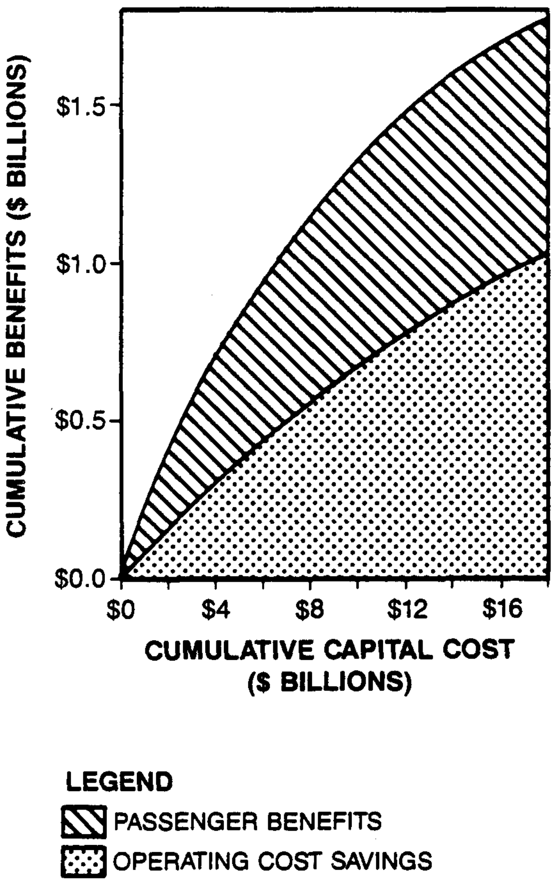
LEGEND
•••••• LTI MODIFIERS
▬▬▬ PASS. MILES/COSTS

The operating cost savings and passenger benefits for the LTI method, illustrated in Figure 5.5, are as follows:

10-Year Capital Expenditure	Annual Operating Cost Savings
$ 8.9 B	$ .6 B
$13.4 B	$ .8 B
$17.8 B	$1.0 B

FIGURE 5.5

OPERATING COST SAVINGS AND PASSENGER BENEFITS ALL SYSTEMS (LTI)



The cumulative benefits versus cumulative capital costs for each of the major rail areas are summarized in the following paragraphs by type of transit system.

o BOSTON

The rapid rail system was separated into 6 segments. The capital costs for full rehabilitation were estimated at $448 million. As shown in Figure 5.6, capital expenditures of between $210 million and $305 million would achieve 80 percent of the expected benefits. At this level of capital expenditure, 3 or 4 of the 6 segments would be funded for improvement.

The light rail system was separated into 7 segments and the capital costs for full rehabilitation were estimated at $345 million. As shown in Figure 5.7, capital expenditures of between $230 million and $275 million would achieve 80 percent of the expected benefits. At this level of capital expenditure, 5 of the 7 segments would be funded for improvement.

FIGURE 5.6

BENEFIT/COST ANALYSIS BOSTON RAPID RAIL

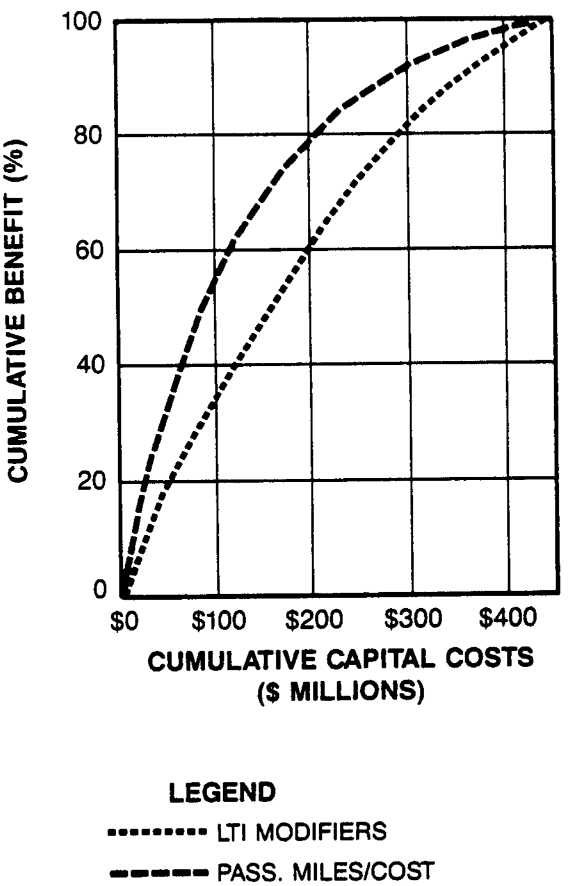
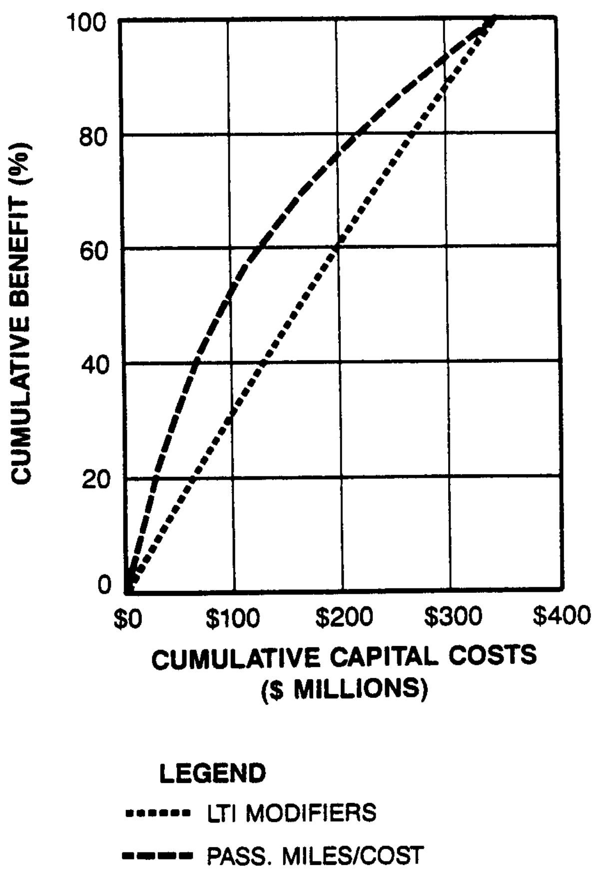


FIGURE 5.7

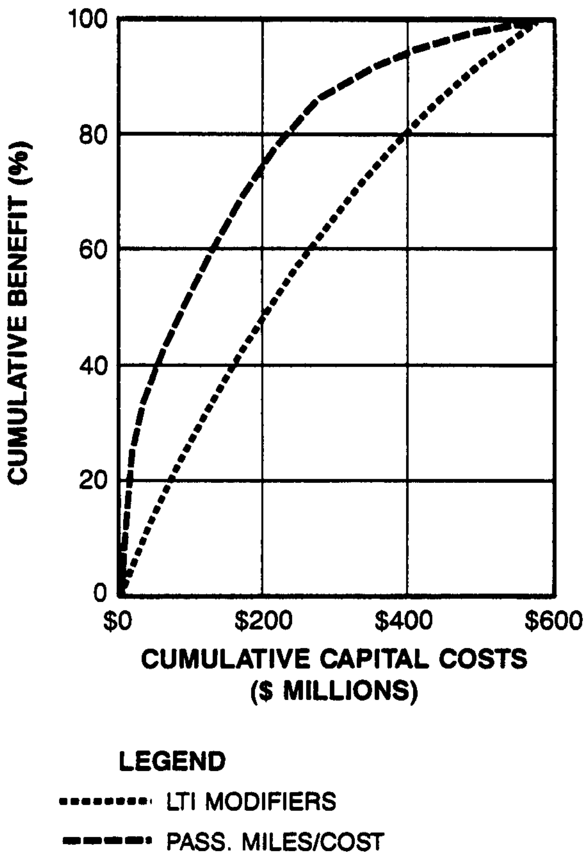
BENEFIT/COST ANALYSIS BOSTON LIGHT RAIL



The commuter rail system was separated into 10 segments and the capital costs for full rehabilitation were estimated at $580 million. As shown in Figure 5.8, capital expenditures of between $240 million and $410 million would achieve 80 percent of the expected benefits. At this level of capital expenditure, between 4 and 7 of the 10 segments would be funded for improvement.

FIGURE 5.8

BENEFIT/COST ANALYSIS BOSTON COMMUTER RAIL

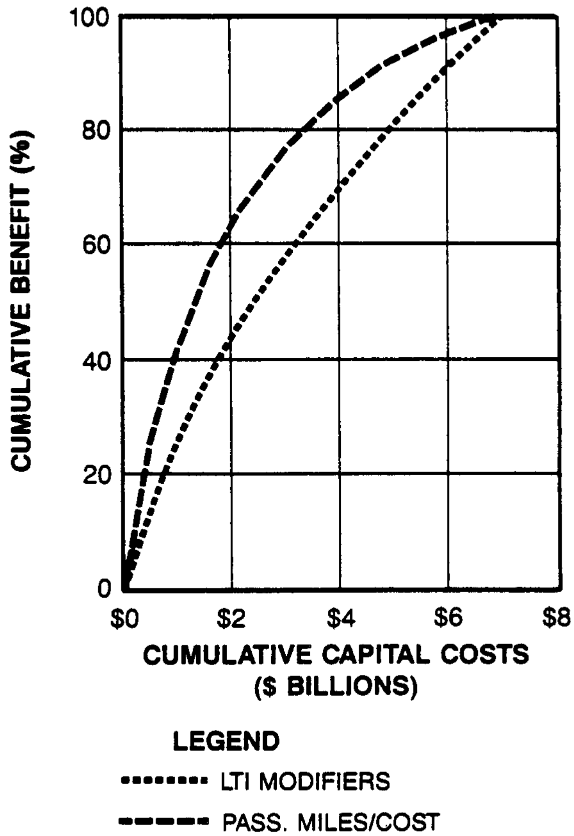


o NEW YORK

The rapid rail systems were separated into 42 segments and the capital costs for full rehabilitation were estimated at $7.035 billion. As shown in Figure 5.9, capital expenditures of between $3.2 billion and $4.7 billion would achieve 80 percent of the expected benefits. At this level of capital expenditure, between 21 and 29 of the 42 segments would be funded for improvement.

FIGURE 5.9

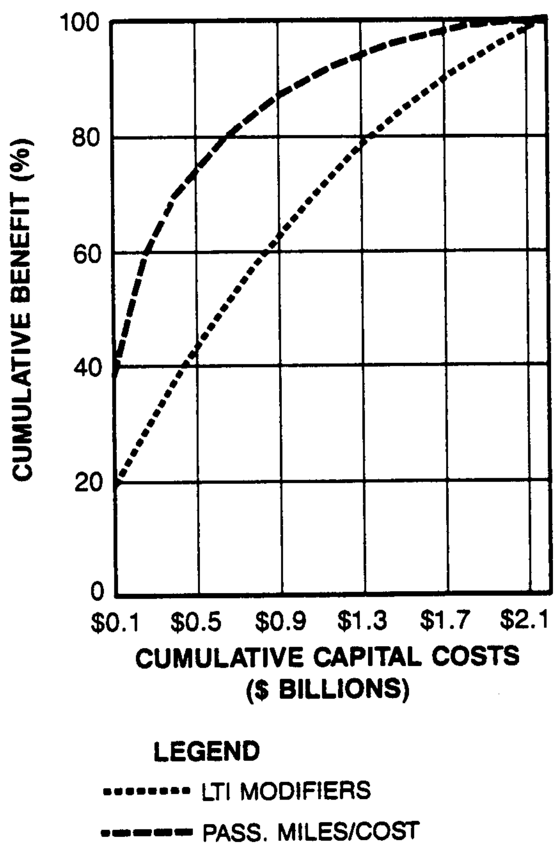
BENEFIT/COST ANALYSIS NEW YORK RAPID RAIL



The commuter rail systems were separated into 25 segments and the capital costs for full rehabilitation were estimated at about $2.2 billion. As shown in Figure 5.10, capital expenditures of between $.7 billion and $1.4 billion would achieve 80 percent of the expected benefits. At this level of expenditure, between 10 and 14 of the 25 segments would be funded for improvement.

FIGURE 5.10

BENEFIT/COST ANALYSIS NEW YORK COMMUTER RAIL

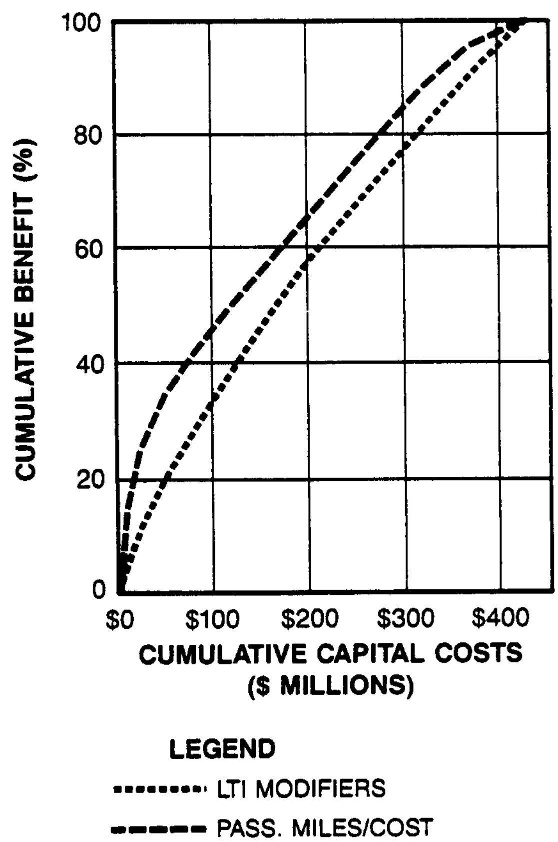


o NEW YORK/
NORTHERN NEW JERSEY

The rapid rail system was separated into 5 segments and the capital costs for full rehabilitation were estimated at about $430 million. As shown in Figure 5.11, capital expenditures of between $280 million and $320 million would achieve 80 percent of the expected benefits. At this level of expenditure, either 2 or 3 of the 5 segments would be funded for improvement.

FIGURE 5.11

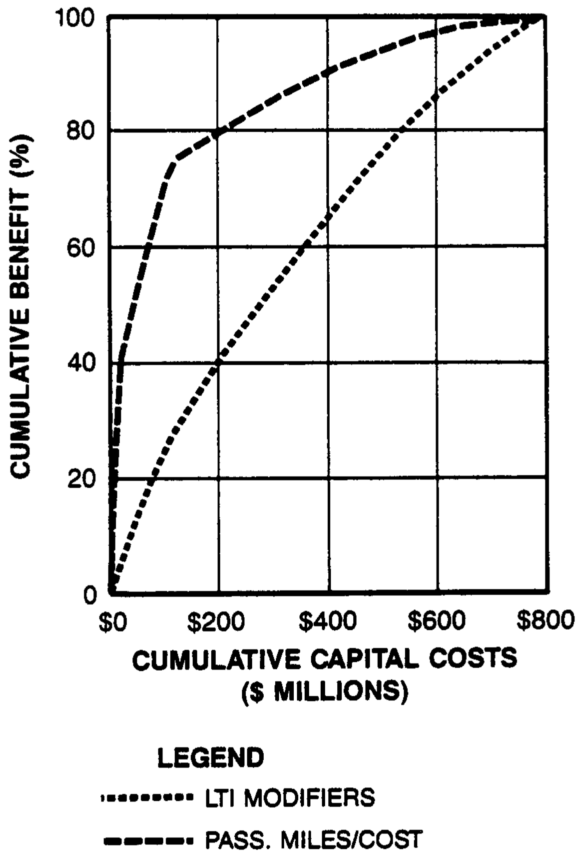
BENEFIT/COST ANALYSIS NEW YORK/NORTHERN NEW JERSEY RAPID RAIL



The light rail and commuter rail systems were separated into 13 segments and the capital costs for full rehabilitation were estimated at about $787 million. As shown in Figure 5.12, capital expenditures of between $200 million and $550 million would achieve 80 percent of the expected benefits. At this level of expenditure, between 6 and 9 of the 13 segments would be funded for improvement.

FIGURE 5.12

BENEFIT/COST ANALYSIS NEW YORK/NORTHERN NEW JERSEY LIGHT RAIL & COMMUTER RAIL

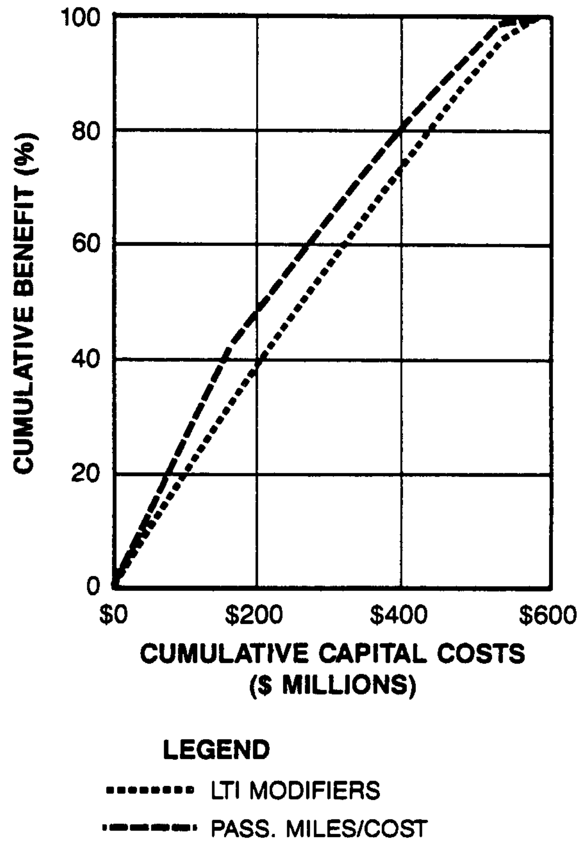


o SOUTHERN NEW JERSEY/ PHILADELPHIA/PITTSBURGH

The rapid rail systems were separated into 6 segments and the capital costs for full rehabilitation were estimated at about $588 million. As shown in Figure 5.13, capital expenditures of between $395 million and $440 million would achieve 80 percent of the expected benefits. At this level of expenditure, 3 of the 6 segments would be funded for improvement.

FIGURE 5.13

BENEFIT/COST ANALYSIS SOUTHERN NEW JERSEY/ PHILADELPHIA/PITTSBURGH RAPID RAIL



The light rail systems were separated into 9 segments and the capital costs for full rehabilitation were estimated at about $483 million. As shown in Figure 5.14, capital expenditures of between $220 million and $350 million would achieve 80 percent of the expected benefits. At this level of expenditure, between 3 and 6 of the 9 segments would be funded for improvement.

The commuter rail systems were separated into 15 segments and the capital costs for full rehabilitation were estimated at $1.26 billion. As shown in Figure 5.15, between $.36 billion and $.92 billion would achieve 80 percent of the expected benefits. At this level of expenditure, between 5 and 12 of the 15 segments would be funded for improvement.

FIGURE 5.14

BENEFIT/COST ANALYSIS SOUTHERN NEW JERSEY/ PHILADELPHIA/PITTSBURGH LIGHT RAIL

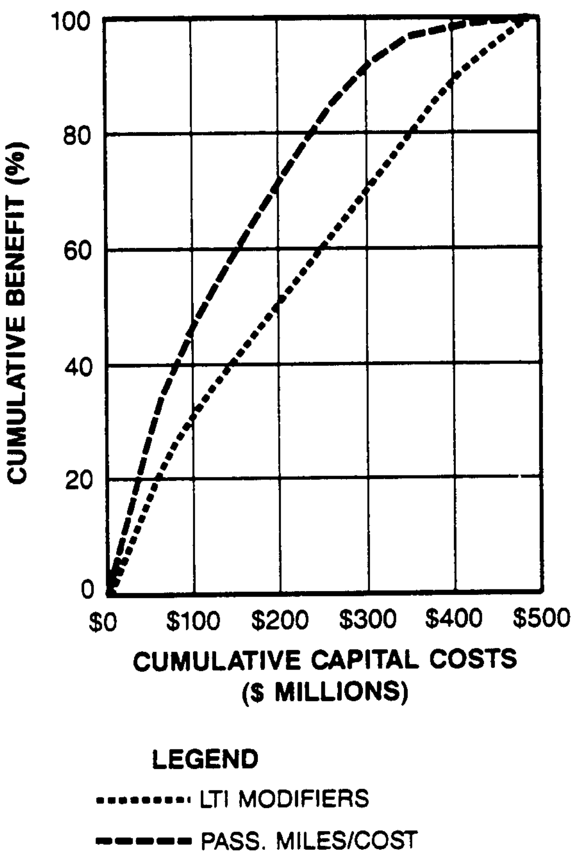
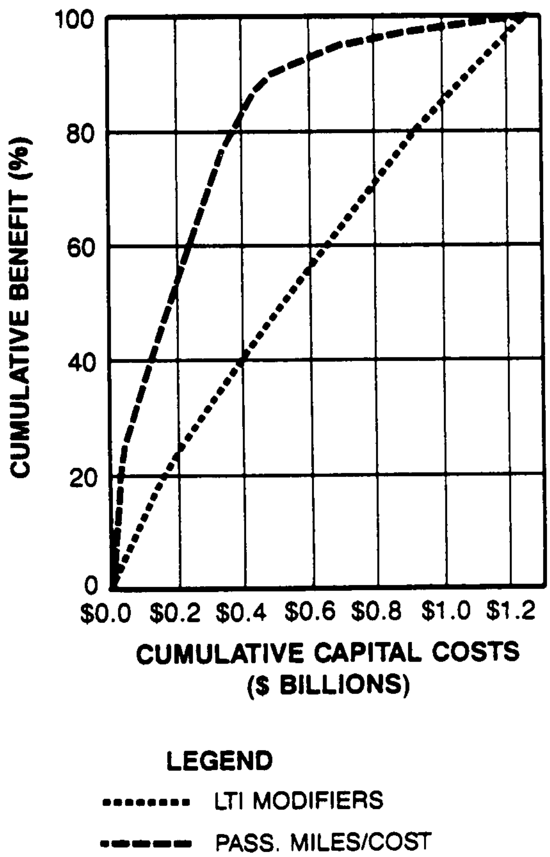


FIGURE 5.15

BENEFIT/COST ANALYSIS PHILADELPHIA/PITTSBURGH COMMUTER RAIL



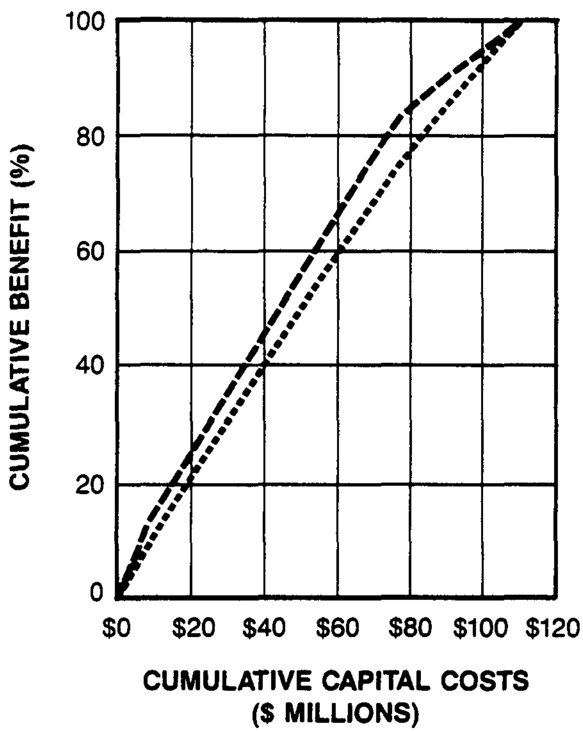
o WASHINGTON, D.C.

The rapid rail system was separated into 4 segments and the capital costs for full rehabilitation were estimated at $111 million. As shown in Figure 5.16, capital expenditures of between $73 million and $86 million would achieve 80 percent of the expected benefits. At this level of expenditure, either 2 or 3 of the 4 segments would be funded for improvement.

The commuter rail system was separated into 3 segments and the capital costs for full rehabilitation were estimated at $28 million. As shown in Figure 5.17, capital expenditures of between $16 million and $21 million would achieve 80 percent of the expected benefits. At this level of expenditure, 2 of the 3 segments would be funded for improvement.

FIGURE 5.16

BENEFIT/COST ANALYSIS WASHINGTON DC RAPID RAIL



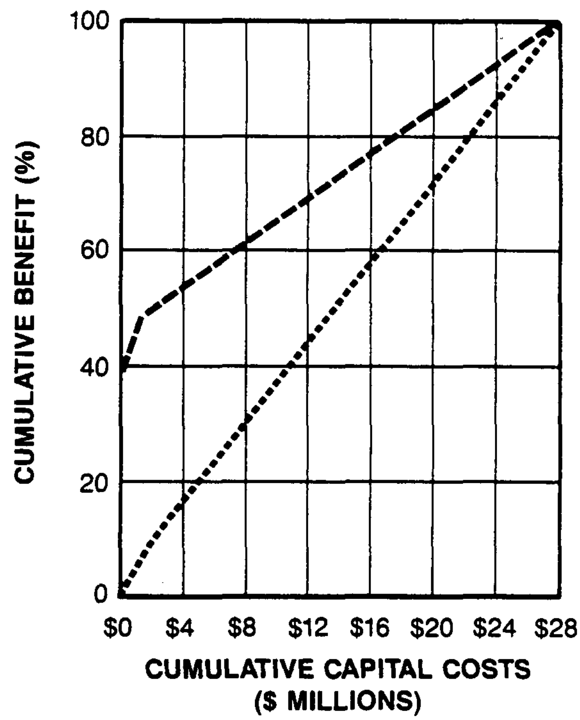
LEGEND

········· LTI MODIFIERS

– – – – – PASS. MILES/COST

FIGURE 5.17

BENEFIT/COST ANALYSIS WASHINGTON DC COMMUTER RAIL



LEGEND

········· LTI MODIFIERS

– – – – – PASS. MILES/COST

o CHICAGO

The <u>rapid rail</u> system was separated into 7 segments and the capital costs for full rehabilitation were estimated at $1.6 billion. As shown in Figure 5.18, capital expenditures of between $1.12 billion and $1.22 billion would achieve 80 percent of the expected benefits. At this level of expenditure, between 4 and 5 of the 7 segments would be funded for improvement.

The <u>commuter rail</u> systems were separated into 13 segments and the capital costs for full rehabilitation were estimated at $1.32 billion. As shown in Figure 5.19, capital expenditures of between $.78 billion and $.93 billion would achieve 80 percent of the expected benefits. At this level of expenditure, between 5 and 7 of the 13 segments would be funded for improvement.

FIGURE 5.18

BENEFIT/COST ANALYSIS CHICAGO RAPID RAIL

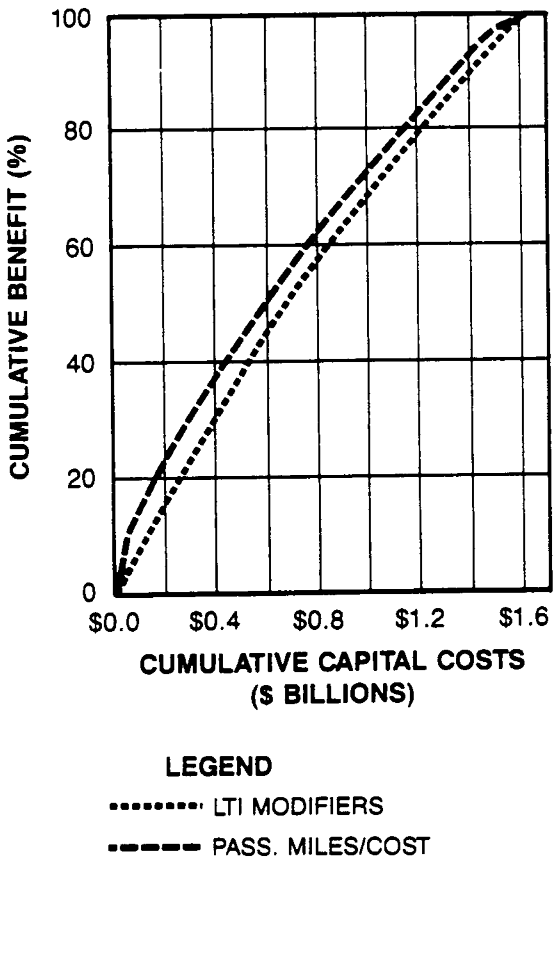
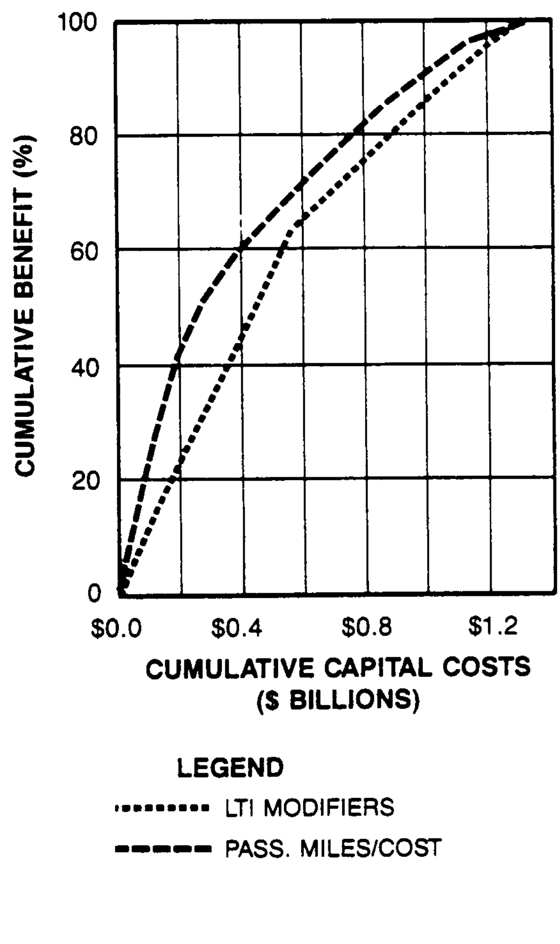


FIGURE 5.19

BENEFIT/COST ANALYSIS CHICAGO COMMUTER RAIL

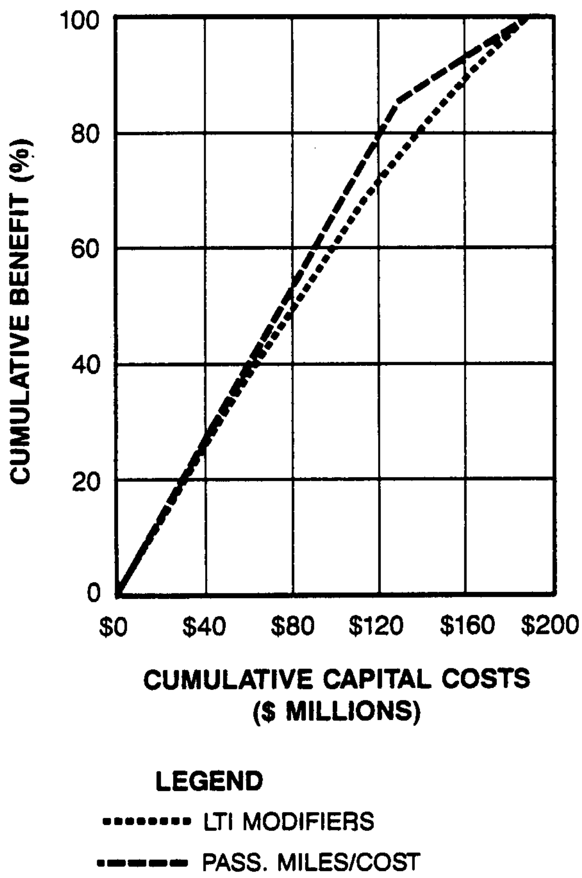


o CLEVELAND

The rapid rail and light rail systems were separated into 3 segments and the capital costs for full rehabilitation were estimated at $188 million. As shown in Figure 5.20, capital expenditures of between $110 million and $140 million would achieve 80 percent of the expected benefits. At this level of expenditure, either 1 or 2 of the 3 segments would be funded for improvement.

FIGURE 5.20

BENEFIT/COST ANALYSIS CLEVELAND RAPID RAIL AND LIGHT RAIL

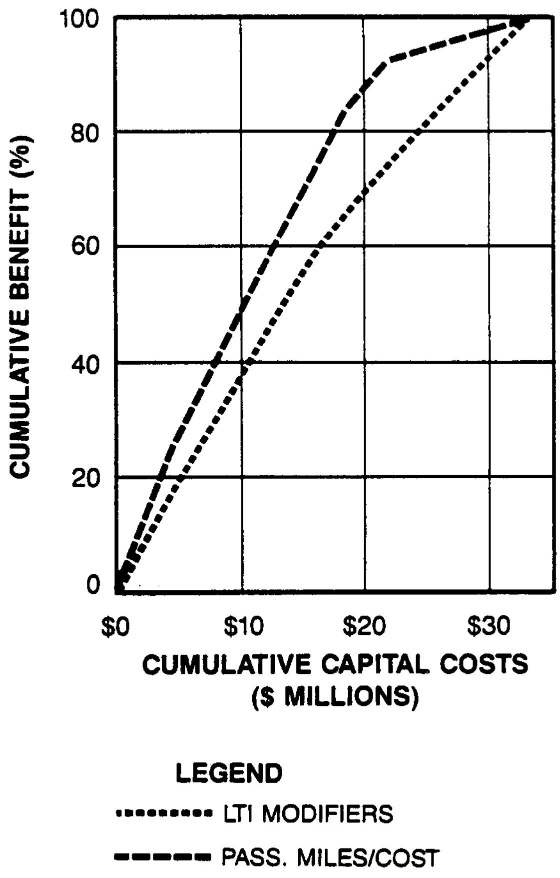


o ATLANTA

The rapid rail system was separated into 4 segments and the capital costs for full rehabilitation were estimated at $33 million. As shown in Figure 5.21, capital expenditures of between $18 million and $25 million would achieve 80 percent of the expected benefits. At this level of expenditure, either 1 or 3 of the 4 segments would be funded for improvement.

FIGURE 5.21

BENEFIT/COST ANALYSIS ATLANTA RAPID RAIL



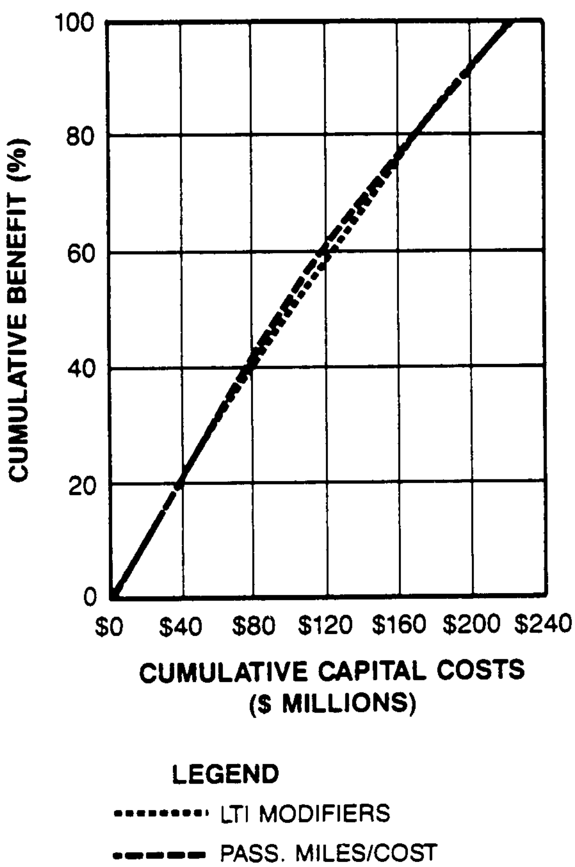
o NEW ORLEANS

The light rail system was not separated into segments. The capital costs for full rehabilitation were estimated at $26 million.

o SAN FRANCISCO/SAN DIEGO

The rapid rail system was separated into 5 segments and the capital costs for full rehabilitation were estimated at $223 million. As shown in Figure 5.22, capital expenditures of between $143 million and $172 million would achieve 80 percent of the expected benefits. At this level of expenditure, either 3 or 4 of the 5 segments would be funded for improvement.

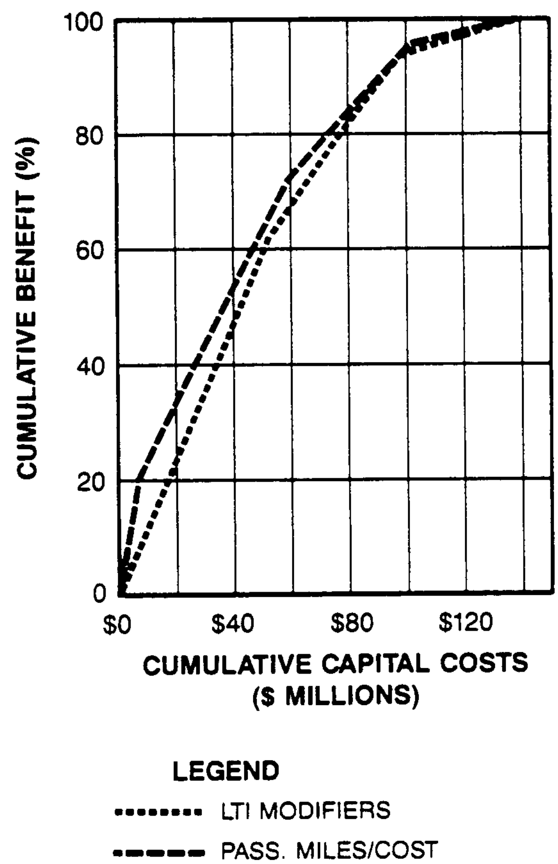
FIGURE 5.22
BENEFIT/COST ANALYSIS
SAN FRANCISCO
RAPID RAIL



The light rail systems have been separated into 7 segments and the capital costs for full rehabilitation were estimated at $138 million. As shown in Figure 5.23, capital expenditures of between $75 million and $81 million would achieve 80 percent of the expected benefits. At this level of expenditure, 3 of the 7 segments would be funded for improvement.

The commuter rail system was not separated into segments and the capital costs for the full rehabilitation were estimated at about $42 million.

FIGURE 5.23
BENEFIT/COST ANALYSIS
SAN FRANCISCO/SAN DIEGO
LIGHT RAIL



5.6 SYSTEM ELEMENT CONDITION FOR VARIOUS CAPITAL EXPENDITURE LEVELS

The expected change in condition, due to investments made to the various system elements provides some indication of the expected benefits to be derived from the capital expenditures. The direct benefits include the reduction in operating costs and increases in operation reliability and availability that are associated with both "bad" and "poor" conditions (i.e., frequent major repairs at intervals of less than 6 months). The indirect benefits can also be assumed to include improvements in safety, security, aesthetics, and amenities.

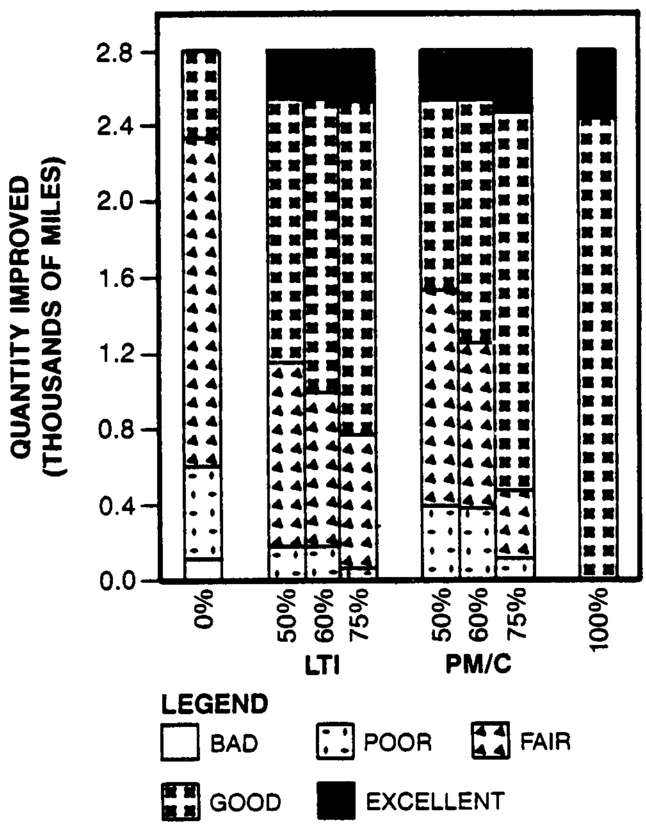
As previously explained, the benefit/cost ratios for each project on each segment were calculated and a summary of the benefit/cost ratios for each of the 186 segments was determined. The transit system segments were then arranged in the order of their benefit/cost ratios with the highest ratios first and those with the lowest ratios last. As a result, the condition of the system elements on the lowest priority segments which might not be undertaken because of low cost-effectiveness is also of interest since it indicates those system elements that would remain in "fair", "poor" or "bad" condition.

The general findings, with respect to both current and expected conditions (resulting from the proposed improvements), are provided in the following sections of this report. However, it should be noted that if all of the proposed projects were funded, 3,000 self-propelled vehicles and 8,200 square feet of stations would remain in "fair" condition because it is not feasible to bring them to "good" condition by the end of the period. The remainder of all of the system elements proposed for improvement would be in either "excellent" or "good" condition. If none of the proposed projects were actually funded, significant portions of the track, self-propelled vehicles, locomotives, unpowered vehicles, etc. would be in "fair", "poor" or "bad" condition. Therefore, the condition of the various system elements at both the 0 and 100 percent levels of funding are provided in the following diagrams as well as the condition of the system elements at 50 percent, 60 percent and 75 percent levels of funding. In addition, the two methods used to prioritize improvements (LTI and passenger mile divided by cost) are compared since there are some significant differences between the ordering of the improvement segments and the resulting condition of the individual system elements.

- o System Element Condition - Track

  The system element condition for various levels of funding for the track system element is illustrated in Figure 5.24. If no improvements

FIGURE 5.24
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (TRACK)



are funded, nearly 430 miles of rapid rail track would be in "fair" or "poor" condition, 128 miles of light rail track would be in "fair" or "poor" condition, and almost 1,800 miles of commuter rail track would be in "fair", "poor" or "bad" condition. At the 100 percent level of funding none of the track would be in "fair", "poor" or "bad" condition.

At the 75 percent level of funding, between 31 and 46 miles of track would be in "fair" condition and between 15 and 48 miles in "poor" condition on the rapid rail systems; between 26 and 33 miles of track would be in "fair" condition, 20 miles in "poor" condition and 1 mile in "bad" condition on the light rail systems; between 289 and 650 miles would be in "fair" condition, between 21 and 41 miles in "poor" condition and none of the track would be in "bad" condition on the commuter rail systems.

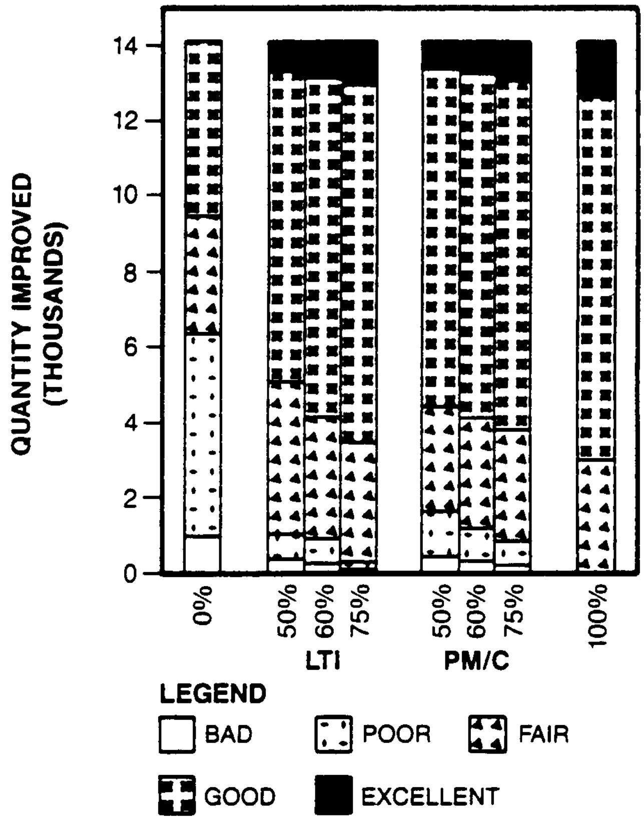
It can also be observed from evaluation of the data in Figure 5.24 that larger percentages of the track would be in "poor" or "fair" condition when the passenger mile per cost ratio is used for establishing priorities than when the LTI method is used.

o System Element Condition -Self-Propelled Rail Cars

The system element condition for the various levels of funding for the self-propelled rail cars is provided in Figure 5.25.

If no funding is provided, more than 7,500 of the self-propelled rail cars on rapid rail systems would be in "fair", "poor" or "bad" condition; nearly 220 of the light rail self-propelled rail cars would be in "fair", "poor" or "bad" condition and

FIGURE 5.25
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (SELF-PROPELLED RAIL CARS)



almost 1,750 of the commuter rail self-propelled rail cars would be in less than "good" condition. If all of the proposed projects were funded, none of the self-propelled rail cars would be in "poor" or "bad" condition but 3,000 of the rail cars would still be in "fair" condition primarily due to deterioration during the 10-year period of rehabilitation and modernization.

At the 75 percent level of funding, between 264 and 836 of the rapid rail self-propelled rail cars would still be in "fair", "poor" or "bad" condition, between 125 and 156 of the light rail self-propelled rail cars would still be in "poor" or "bad" condition, and between 237 and 285 of the self-propelled rail cars on the commuter rail systems would be in "fair", "poor" or "bad" condition.

The information in Figure 5.25 indicates that there are only slight differences between the condition remaining after the improvements for the two different methods of prioritizing improvement projects and transit system segments.

- o System Element Condition -Locomotives

The system element condition for various levels of funding for locomotives is provided in Figure 5.26. If none of the proposed projects were funded, nearly 120 of the locomotives on the commuter rail systems would be in "fair", "poor" or "bad" condition. However, if all of the projects were funded, none of the locomotives would be in less than "good" condition.

The information in Figure 5.26 does indicate some differences in the results using the two different methods of prioritizing projects but the differences are not significant for the 50 percent and 60 percent level of funding.

- o System Element Condition -Unpowered Cars

The condition of the unpowered cars is illustrated in Figure 5.27 for

FIGURE 5.26
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (LOCOMOTIVES)

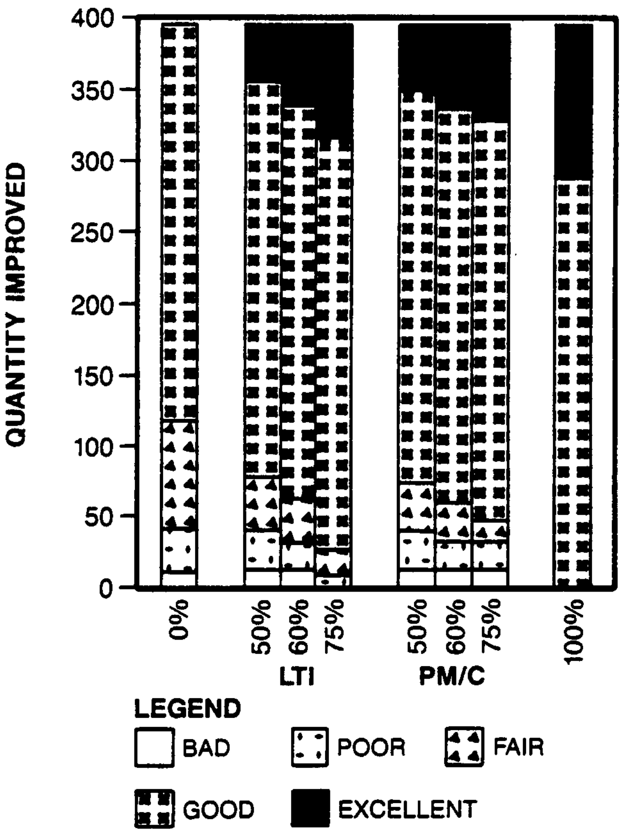
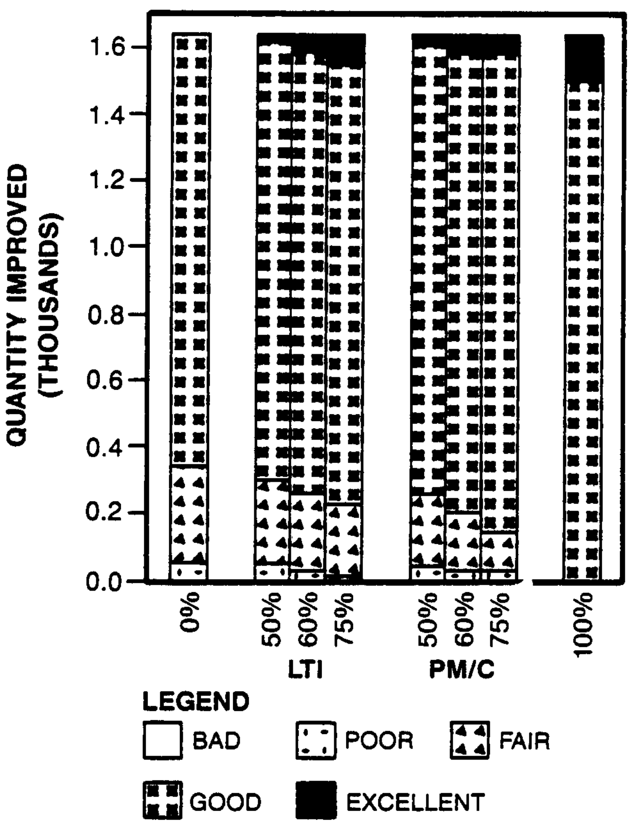


FIGURE 5.27
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (UNPOWERED CARS)



various levels of funding. If none of the projects were funded, nearly 350 of the unpowered cars would be in "fair" or "poor" condition. If all of the proposed projects were funded, then none of the unpowered cars would be in less than "good" condition. At the 75 percent funding level, between 140 and 228 of the unpowered cars would be in "fair", "poor" or "bad" condition.

The differences in condition for the two methods of estimating priorities is not significant for the unpowered car evaluation.

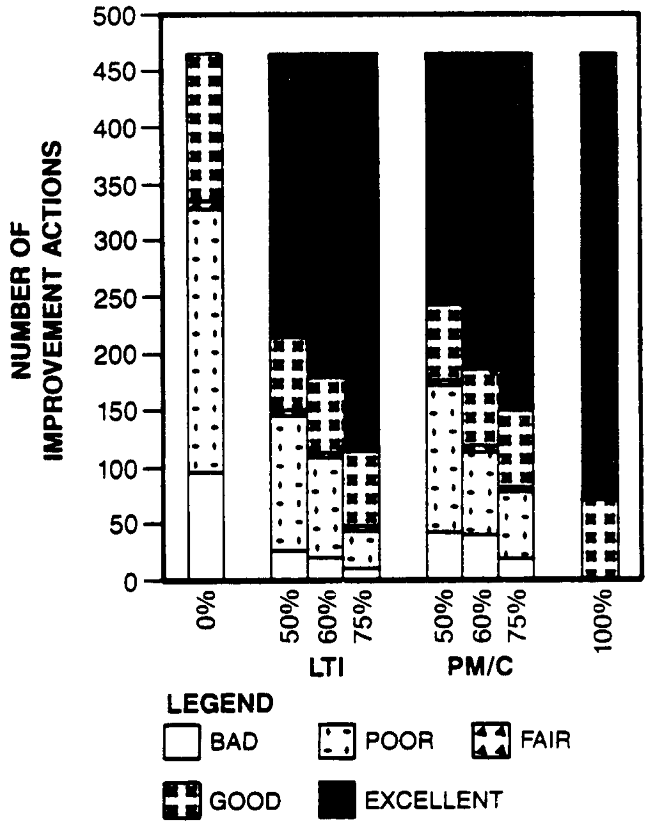
o System Element Condition -Substations

The system element condition for various levels of funding for the substation subsystems is provided in Figure 5.28. If none of the proposed projects were funded, 240 of the proposed rapid rail substation subsystem improvement projects would not be completed and the subsystem elements or subsystems would remain in "poor" or "bad" condition. In addition, 8 of the light rail and almost 90 of the commuter rail substation subsystem improvement projects would not be completed and the subsystem elements or subsystems would remain in "fair", "poor" or "bad" condition. If all of the proposed projects were funded, none of the substation subsystems would be in less than "good" condition.

At the 75 percent level of funding, between 20 and 51 of the rapid rail substation subsystem improvement projects would not be funded and the substation elements or subsystems would remain in "poor" or "bad" condition. In addition, between 4 and 8 of the light rail substation subsystem improvement projects would not be funded and the subsystem elements or subsystems would remain in "bad" condition. Also, more than 20 of

FIGURE 5.28

SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (SUBSTATIONS)



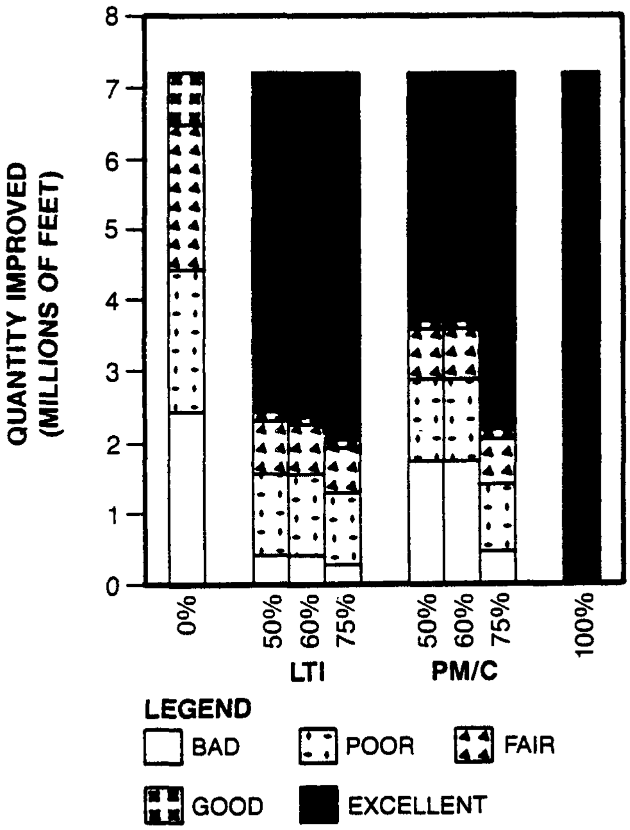
the substation subsystem improvement projects on the commuter rail systems would not be funded and the subsystem elements or subsystems would remain in "fair", "poor" or "bad" condition.

The differences in condition for the two methods of prioritizing projects can best be observed in Figure 5.28 with much greater numbers being in "bad" and "poor" condition when the passenger mile per cost ratio is used to prioritize projects.

o System Element Condition -Overhead Wire

The system element for various levels of funding for overhead wire is provided in Figure 5.29. If no

FIGURE 5.29
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (OVERHEAD WIRE)



improvements were funded, the improvement projects for 1.2 million feet of rapid rail wire, .7 million of light rail wire, and 4.6 million feet of commuter rail wire would not be completed. These improvement projects would result in this wire being in less than "good" condition due to the condition of associated subsystems. If all of the proposed projects were funded, then none of the overhead wire would be in less than "good" condition.

At the 75 percent funding level, the improvement projects for between 26,000 and 60,000 feet of overhead wire on the rapid rail systems would not be completed and would be in less than "good" condition due to the condition of associated subsystems. In addition, improvement projects for between 600,000 and 670,000 feet of light rail overhead wire would not be completed and this wire would be in less than "good" condition for the same reason. Also, improvement projects for approximately 1.3 million feet of commuter rail overhead wire would not be completed resulting in this wire being in less than "good" condition.

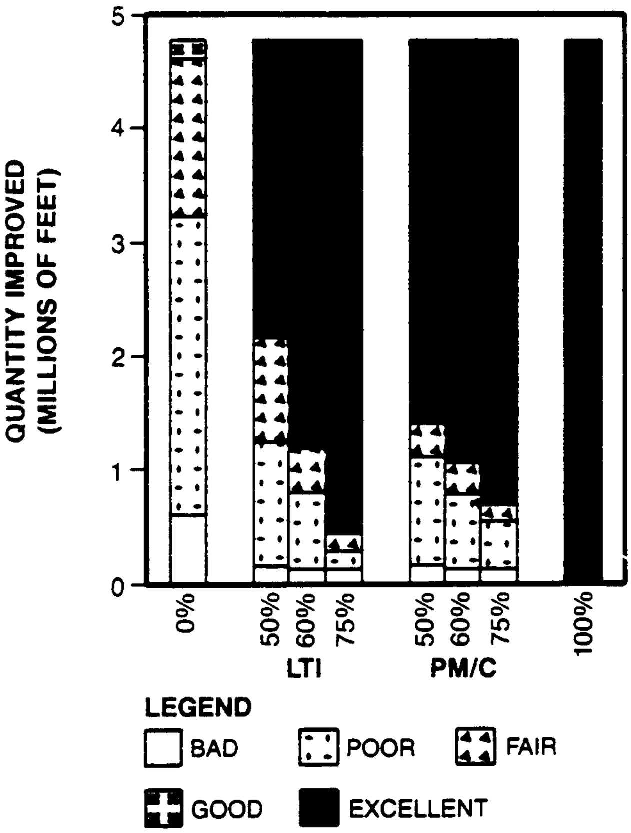
The differences in condition in the methods of estimating priorities is significant at funding levels of less than 75 percent as shown in Figure 5.29. As shown in this figure, when the passenger mile per ratio method of prioritizing is used at the 50 percent funding level, improvement projects for almost 3 million feet of wire would not be completed resulting in this wirebeing in "bad" or "poor" condition due to the condition of associated subsystems.

o System Element Condition - Third Rail

The system element condition for various levels of funding for the third rail is provided in Figure 5.30. If no funding is provided then improvement projects for 3 million feet of third rail would not be completed on the rapid rail resulting in this third rail being in less than "good" condition due to the condition of associated subsystems. In addition, improvement projects for .1 million feet of third rail on the light rail systems and 1.5 million feet of third rail on the commuter rail systems would not be completed resulting in this rail being in less than "good" condition due to the condition of associated subsystems. At the 100 percent level of funding, none of the third rail would be in less than "good" condition.

At the 75 percent funding level, improvement projects for approximately .4 million feet of

FIGURE 5.30
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (THIRD RAIL)



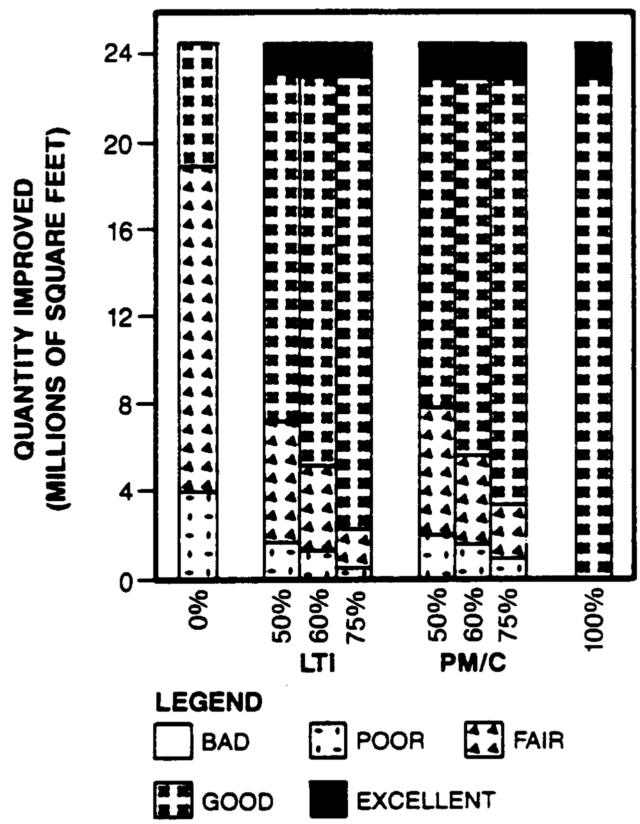
third rail on the rapid rail systems would not be completed resulting in this third rail being in less than "good" condition due to the condition of associated subsystems. In addition, improvement projects for .1 million feet of third rail on the light rail systems would not be completed resulting in this third rail being in less than "good" condition for the same reason. Also, improvement projects for almost .2 million feet of third rail on the commuter rail systems would not be completed resulting in this third rail being in less than "good" condition.

The differences in condition for the two methods of estimating priorities indicates that smaller amounts of third rail would be in less than "good" condition at the 50 percent level of funding when the LTI method is used.

o System Element Condition -Stations

The system element condition for various levels of funding for the station system element is illustrated in Figure 5.31. If no funding is provided, then approximately 15.2 million square feet of station area would be in less than "good" condition for the rapid rail systems, .3 million square feet of light rail station area would be in less than "good" condition, and 3.4 million square feet of station area for the commuter rail would be in less than "good" condition. If all projects are funded, only 8,200 square feet would remain in "fair" condition.

FIGURE 5.31
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (STATIONS)



At the 75 percent funding level, between .7 and 2.3 million square feet of station area would be in less than "good" condition for the rapid rail systems, nearly .3 million square feet of station areas on the light rail systems would be in less than "good" condition and between .9 and 1.3 million square feet of station area on the commuter rail systems would be in less than "good" condition.

The differences in condition for the two methods of estimating priorities indicate that the passenger mile per cost ratio method would result in more of the station area being in "poor" or "fair" condition than when using the LTI method.

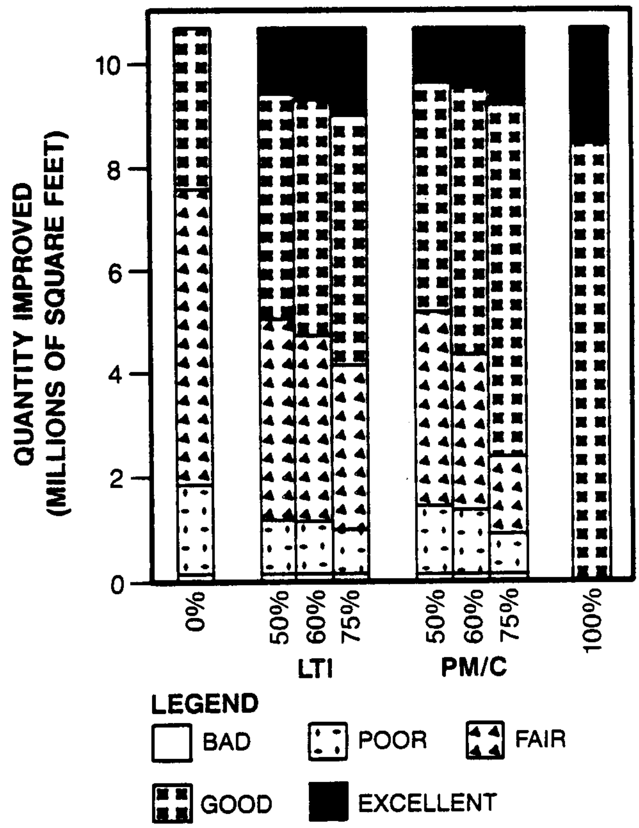
o System Element Condition -Bridges

The system element condition for the bridge system element is illustrated in Figure 5.32. If no funding is provided then almost 1 million square feet of bridges on the rapid rail system would be in less than "good" condition, .23 million square feet of light rail bridges would be in less than "good" condition, and 6.4 million square feet of commuter rail bridges would be in less than "good" condition. If all of the proposed projects were funded, none of the bridge area would be in less than "good" condition.

At the 75 percent level of funding, between .2 and .4 million square feet of bridges on the rapid rail systems would be in less than "good" condition, between .13 and .15 million square feet of bridges on the light rail systems would be in less than "good" condition, between 1.8 and 3.9 million square feet of bridge area on the commuter rail systems would be in less than "good" condition.

The differences in condition for the two different methods of estimating priorities is not considered to be significant although greater amounts of bridge area would be in "poor" or "fair" condition when the passenger mile per cost ratio is used for prioritizing improvements.

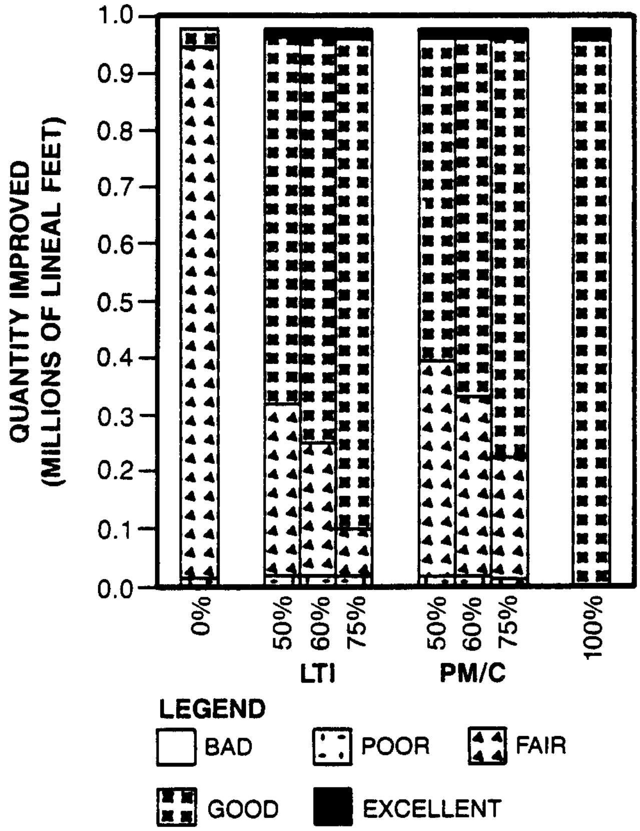
FIGURE 5.32
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (BRIDGES)



o System Element Condition -Elevated Railways

The system element condition for various levels of funding for the elevated railway system element is provided in Figure 5.33. If no funding is provided, then approximately .9 million lineal feet of elevated railway on the rapid rail systems would be in less than "good" condition, 4,300 lineal feet of elevated railway on the light rail systems would be in less than "good"

FIGURE 5.33
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (ELEVATED RAILWAY)



condition and about 52,000 lineal feet of elevated railway on the commuter rail systems would be in less than "good" condition. At the 100 percent level of funding, none of the elevated railways would be in less than "good" condition.

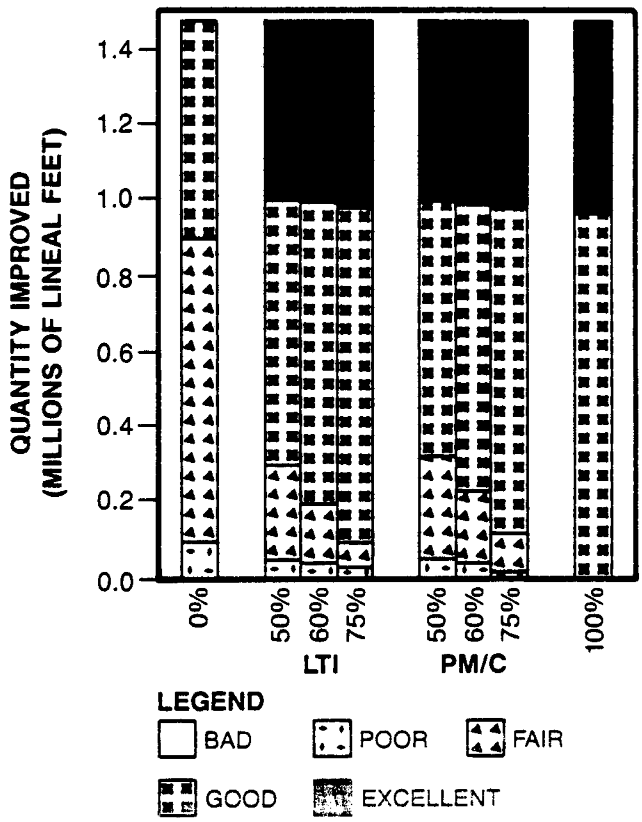
At the 75 percent level of funding, between 73,000 and 211,000 lineal feet of elevated railway would be in less than "good" condition on the rapid rail systems, 4,300 lineal feet of elevated railway on the light rail systems would be in less than "good" condition, and between 8,000 and 21,000 lineal feet of elevated railway on the commuter rail systems would be in less than "good" condition.

The differences in condition for the two different methods of estimating priorities shows that more of the elevated railway would be in "poor" or "fair" condition when the passenger mile per cost ratio is used for prioritizing projects than when the LTI method is used.

o System Element Condition -Tunnels

The system element condition for various levels of funding for the tunnel system element is provided in Figure 5.34. If no funding is provided, approximately .8 million lineal feet of tunnels on the rapid rail systems would be in less than "good" condition, about 21,000 lineal feet of tunnel on the light rail systems would be in less than "good"

FIGURE 5.34
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (TUNNELS)



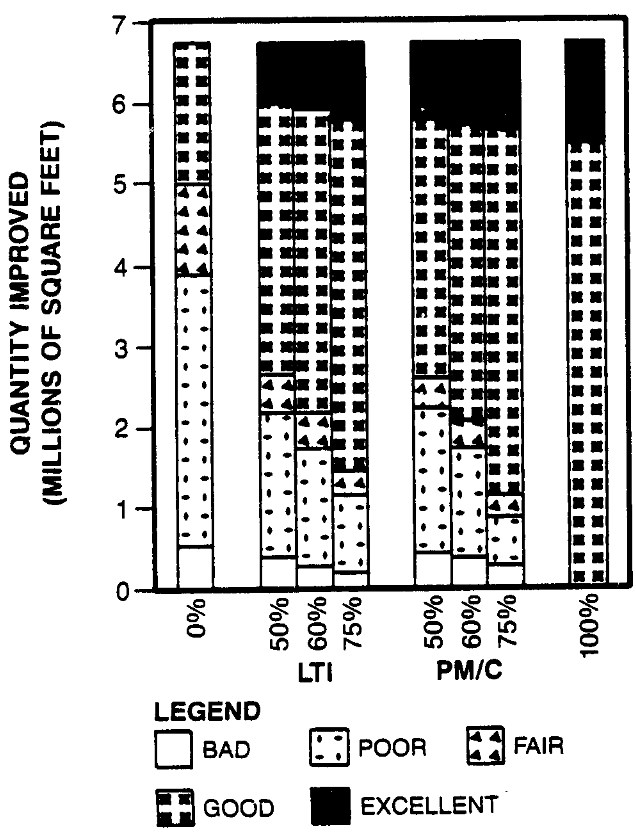
condition, and about 62,000 lineal feet of tunnel on the commuter rail systems would be in less than "good" condition. At the 100 percent level of funding, none of the tunnel areas would be in less than "good" condition.

The differences in condition for the two different methods of estimating priorities is not considered to be significant although slightly more of the tunnels would be in "poor" or "fair" condition when the passenger mile per cost ratio is used for prioritizing improvement projects.

o System Element Condition -Maintenance Facility Buildings

The system element condition for various levels of funding for the maintenance facility system element is provided in Figure 5.35. If no

FIGURE 5.35
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (MAINTENANCE FACILITY BUILDINGS)



funding is provided, then about 2.5 million square feet of maintenance facility buildings on the rapid rail systems would be in less than "good" condition, about .4 million square feet of maintenance facility buildings on the light rail systems would be in less than "good" condition, and 2.1 million square feet of maintenance facility buildings on the commuter rail systems would be in less than "good" condition.

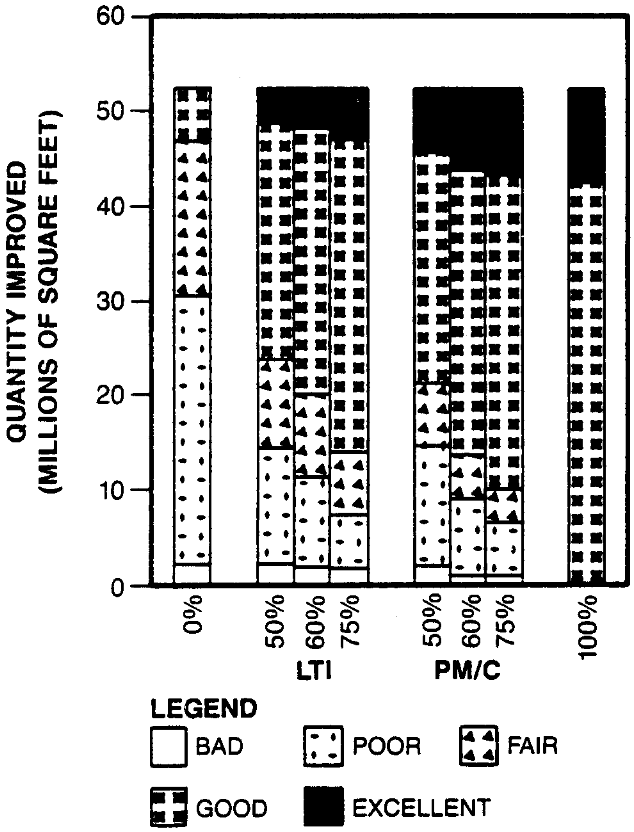
At the 75 percent level of funding, between .1 and .4 million square feet of maintenance facility buildings on the rapid rail systems would be in less than "good" condition, between .2 and .3 million square feet of maintenance facility buildings on the light rail systems would be in less than "good" condition, and between .6 and 1.0 million square feet of maintenance facility buildings on the commuter rail systems would be in less than "good" condition.

The differences in condition for the two methods of estimating priorities is not considered to be significant as shown in Figure 5.35.

o System Element Condition -Maintenance Facility Yards

The system element condition for the various levels of funding for the maintenance facility yards is illustrated in Figure 5.36. If no funding is provided, then approximately 23.6 million square feet of maintenance facility yards would be in less than "good" condition on the rapid rail systems, 1.1 million square feet of maintenance facility yards on the light rail systems would be in less than "good" condition, and 22.1 million square feet of maintenance facility yards on the commuter rail systems would be in less than "good" condition.

FIGURE 5.36
SYSTEM ELEMENT CONDITION FOR VARIOUS LEVELS OF FUNDING (MAINTENANCE FACILITY YARDS)



At the 75 percent level of funding, between 2.1 and 4.3 million square feet of maintenance facility yards on the rapid rail systems would remain in less than "good" condition, about 1.0 million square feet of maintenance facility yards on the light rail systems would remain in less than "good" condition and between 4.7 and 10.9 million square feet of maintenance facility yards on the commuter rail systems would remain in less than "good" condition.

The differences in condition for the two methods of estimating priorities is not considered to be significant although the passenger mile per cost ratio method of prioritizing projects results in somewhat lower percentages of the yards being in "poor" or "bad" condition for the 60 percent and 75 percent levels of funding.

5.7 ASSESSMENT OF BENEFITS AND CAPITAL COSTS FOR VARIOUS EXPENDITURE LEVELS.

The benefits and costs for various expenditure levels were developed and the results are presented in the following sections of this report.

If all of the proposed improvements were funded, the total capital costs, by type of transit system and system element, would be as shown in Table 5.5.

TABLE 5.5

Total Capital Costs to Fully Rehabilitate the Transit Systems

($-Billions of 1983 Dollars)

System Element	Rapid Rail	Light Rail	Commuter Rail	Total	Percent
Track	0.564	0.194	1.142	1.900	10.6%
Vehicles	1.966	0.374	1.032	3.372	18.9%
Power Distribution	0.881	0.187	0.510	1.578	8.8%
System-Wide Controls	1.704	0.101	0.894	2.699	15.1%
Stations	2.641	0.041	0.515	3.197	17.9%
Structures & Facilities	1.989	0.099	1.456	3.544	19.8%
Maintenance Facilities	0.875	0.056	0.655	1.586	8.9%
Total	10.620	1.052	6.204	17.876	100.0%
Percent	59.4%	5.9%	34.7%	--	100.0%

Two methods of assessing the cost effectiveness of the improvements were developed. These methods provide for the "most worthy" rail segment improvements to be accomplished first and some segment improvements to be completed later or not to be done at all. As previously explained, all of the 186 segments were prioritized according to their benefit/cost ratios, with the highest ratios first and the lowest last. The results of this analysis are provided in the following sections.

- o Assessment of Benefits for Various Expenditure Levels

The expected benefits for various levels of funding for all of the transit systems evaluated are provided in Figure 5.37. At the 50 percent funding level, it is anticipated that between 69 percent and 84 percent of the benefits would be obtained depending upon the method used to establish the benefits. As indicated in this figure, the passenger mile per cost ratio provides a higher level of benefit than the LTI method.

At the 60 percent level, between 77 percent and 90 percent of the benefits would be anticipated. At the 75 percent level, between 88 percent and 96 percent of the benefits would be anticipated.

The estimated benefits for various levels of funding for the different types of transit types, using the passenger mile per cost ratio method of prioritization, are provided in Figure 5.38. At the 50 percent level of funding, approximately 54

FIGURE 5.37
BENEFITS FOR VARIOUS LEVELS OF FUNDING (ALL SYSTEMS)

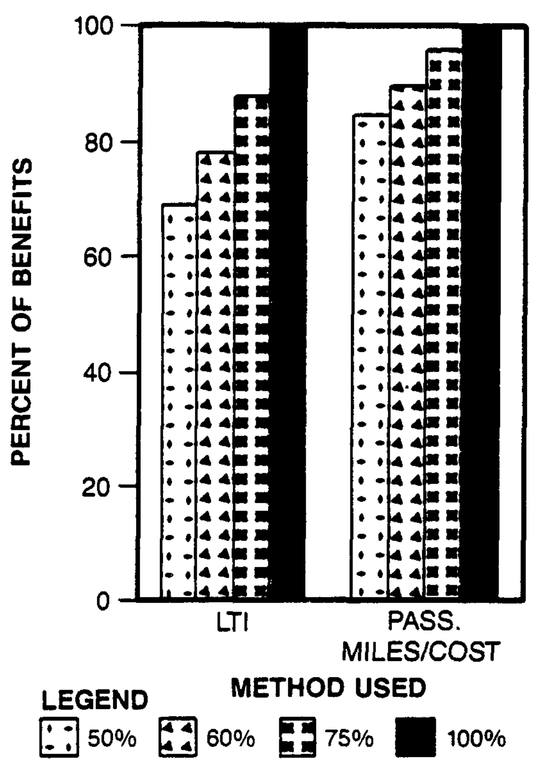
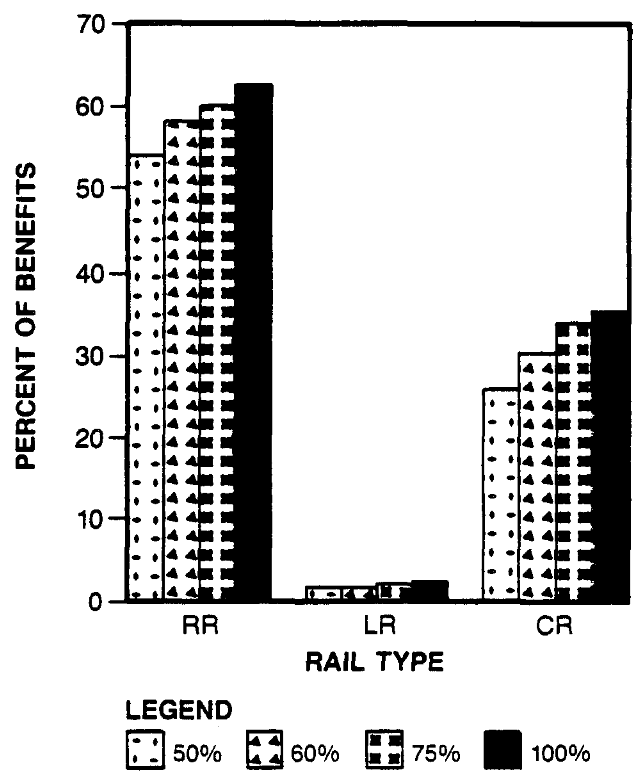


FIGURE 5.38
BENEFITS FOR VARIOUS LEVELS OF FUNDING (PASSENGER MILES/ COST METHOD)



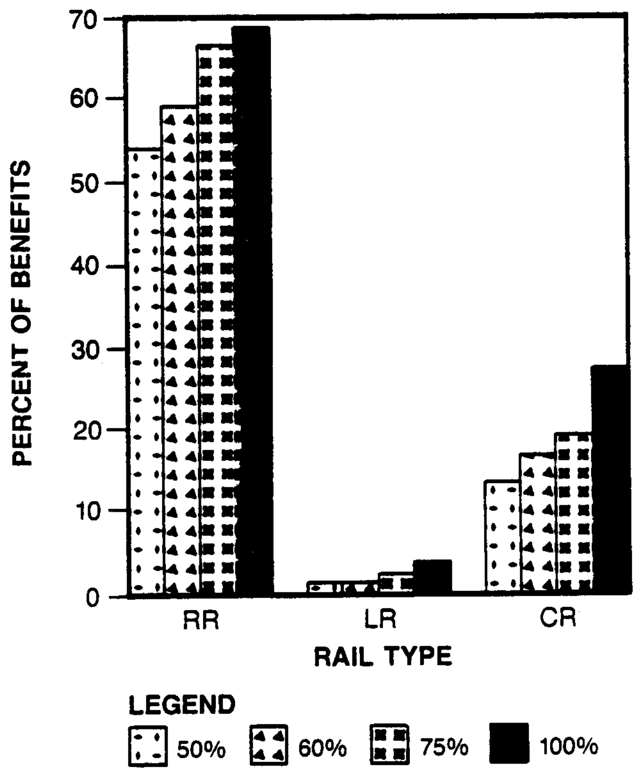
percent of the benefits from all rail system improvements would be derived by the rapid rail systems, less than 2 percent of the benefits would be derived by the light rail systems, and nearly 26 percent of the benefits would be obtained by the commuter rail systems. At the 60 percent level of funding, benefits increased to 58 percent for rapid rail and 30 percent for commuter rail, with the benefits expected to be derived by the light rail systems remaining constant. At the 75 percent level of funding, the benefits to be derived by the rapid rail systems increase to 60 percent and to approximately 34 percent by the commuter rail systems with the light rail systems indicating only a slight increase in the total benefits.

The expected benefits for various levels of funding using the LTI method are provided in Figure 5.39. At the 50 percent level of funding, approximately 54 percent of the total benefits would be derived by the rapid rail systems, less than 2 percent by the light rail systems, and nearly 14 percent by the commuter rail systems. As the level of funding increases to 60 percent, the benefits to the rapid rail systems increase to 59 percent, to 17 percent for the commuter systems and remain approximately the same at 2 percent for the light rail systems. If the funding level were increased to 75 percent, then the benefits would increase to 66 percent for rapid rail, to less than 3 percent for light rail, and to 19 percent for the commuter rail systems.

o Assessment of Costs for Various Expenditure Levels

The estimated capital costs for various funding levels are provided in Figure 5.40 through 5.46 for each of the system elements.

FIGURE 5.39
BENEFITS FOR VARIOUS LEVELS OF FUNDING (LTI METHOD)



The estimated costs for various funding levels for the track system element are provided in Figure 5.40. At the 50 percent level of funding, total costs range from $.7 to $.8 billion depending upon the method used to prioritize the segments. The estimated cost for rapid rail track improvements are between $.36 and $.37 billion, for light rail between $59 and $95 million and for commuter rail between $.3 and $.35 billion. At the 60 percent level of funding, the total costs range from $.9 to $1.1 billion. The costs for fully rehabilitating the track for the rapid rail systems were estimated at about $.4 billion, between $63 and $95 million for light rail and between $.4 and $.55 billion for

FIGURE 5.40
COSTS FOR VARIOUS LEVELS OF FUNDING (TRACK)

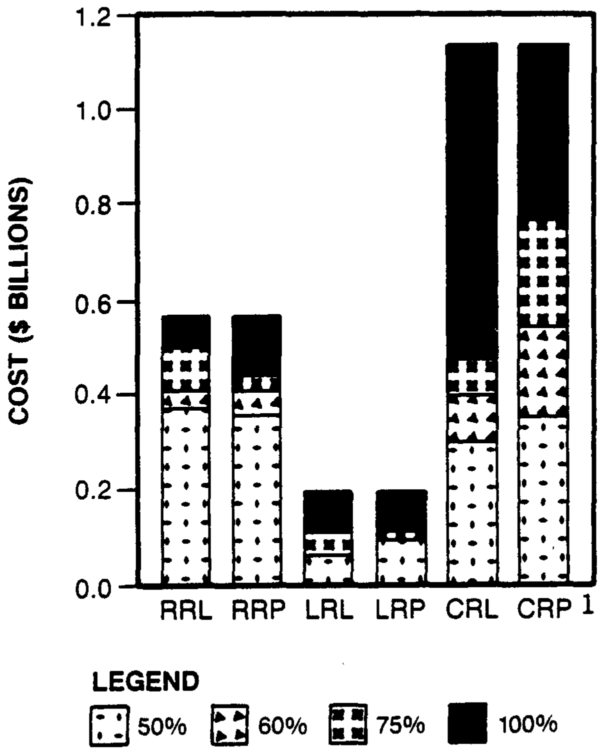
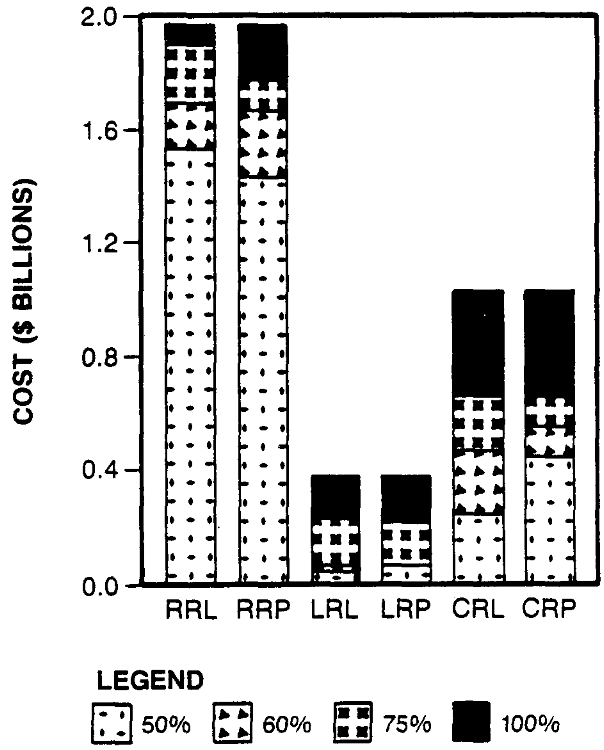


FIGURE 5.41
COSTS FOR VARIOUS LEVELS OF FUNDING (VEHICLES)



commuter rail. At the 75 percent funding level, the total costs were estimated at between $1.1 and $1.3 billion. The rapid rail system track improvements were estimated at between $.4 and $.5 billion, approximately $.1 billion for light rail and between $.5 and $.8 billion for commuter rail.

The estimated costs for the various funding levels for the proposed vehicle improvements are provided in Figure 5.41. At the 50 percent funding level, the total costs range from $1.8 to $1.9 billion. The proposed improvements for vehicles range from $1.4 to $1.5 billion for the rapid rail systems, between $40 and $55 million for the light rail systems, and between $.2 and $.4 billion for the commuter rail systems. At the 60 percent level of funding, total costs range from $2.2 to $2.3 billion. The costs for rehabilitating the rapid rail vehicles were estimated at about $1.7 billion, $55 million for light rail and between $.47 and $.55 billion for commuter rail systems. At the 75 percent level of funding, the total costs range from $2.6 billion to $2.8 billion. The rapid rail vehicle improvements were estimated at between $1.8 and $1.9 billion, between $.21 and $.23 billion for light rail, and about $.65 billion for the commuter rail systems.

[1]Definitions: RRL = Rapid Rail (LTI), RRP = Rapid Rail (Passenger Mile), LRL = Light Rail (LTI), LRP = Light Rail (Passenger Mile), CRL = Commuter Rail (LTI), CRP = Commuter Rail (Passenger Mile)

The estimated capital costs for various funding levels for power are provided in Figure 5.42. At the 50 percent level of funding, the total costs range from $.73 billion to $.78 billion. The proposed rapid rail power improvements were estimated at about $.5 billion, the light rail power improvements were estimated at between $4 and $21 million, and the commuter rail improvements range from $.21 to $.24 billion. At the 60 percent funding level, the total costs were estimated at about $.9 billion. Power improvements for the rapid rail systems were estimated at between $.62 and $.66 billion, light rail between $4 and $21 million and between $.21 and $.26 billion for the commuter rail systems. At the 75 percent level of funding, the total costs for rehabilitating the power systems range from $1.03 to $1.15 billion. The estimated costs for the power improvements for the rapid rail system range from $.71 billion to $.82 billion, between $4 and $21 million for the light rail systems and between $.31 and $.32 billion for the commuter rail systems.

The estimated costs for funding the system-wide control improvements at various funding levels are provided in Figure 5.43. At the 50 percent level of funding, the costs range from $1.2 billion to $1.3 billion. The costs for rehabilitating the rapid rail system-wide controls range from $1.0 to $1.1 billion, approximately $30 million for light rail, and approximately $.2 billion for commuter rail systems. At the

FIGURE 5.42
COSTS FOR VARIOUS LEVELS OF FUNDING (POWER)

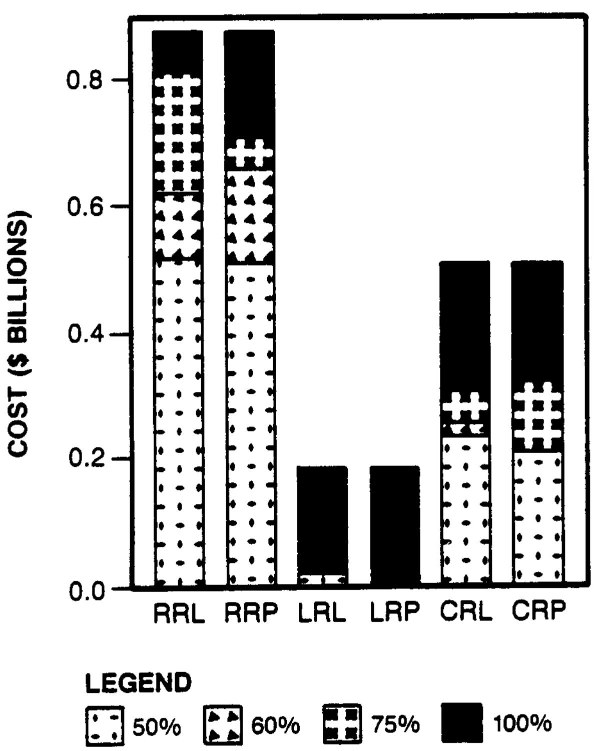
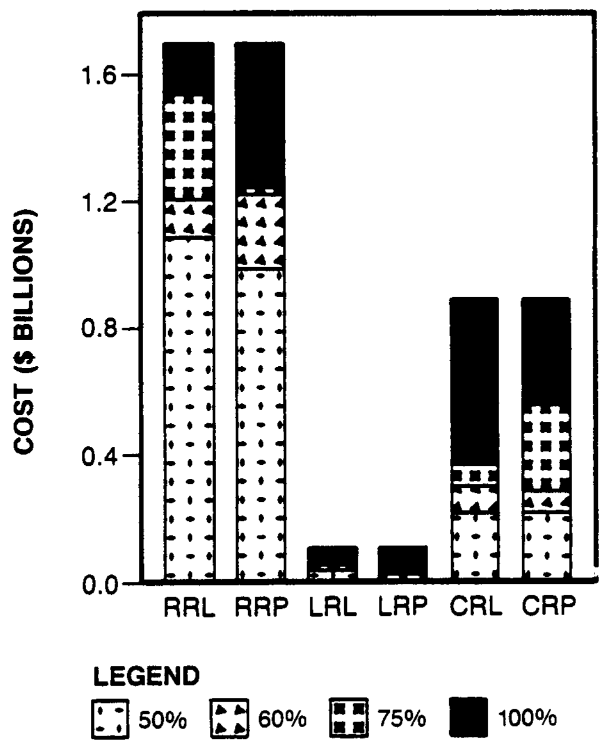


FIGURE 5.43
COSTS FOR VARIOUS LEVELS OF FUNDING (SYSTEM WIDE CONTROLS)

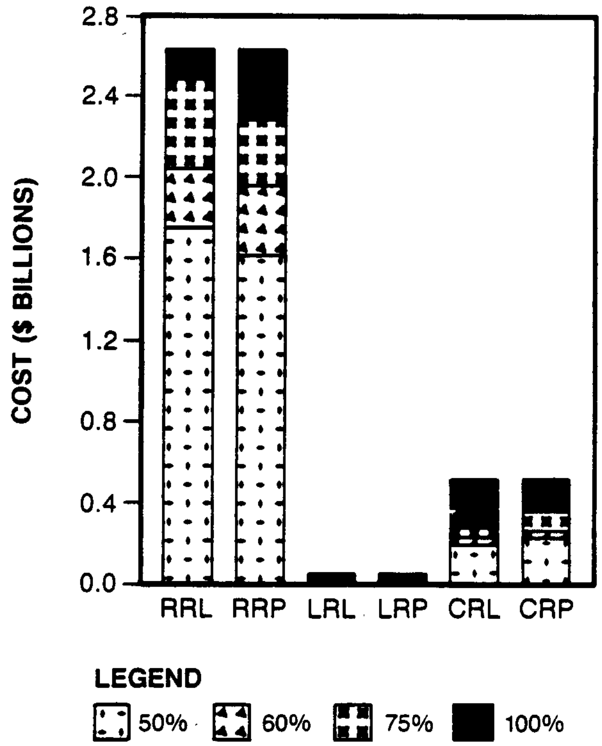


60 percent level of funding, the total costs were estimated at approximately $1.54 billion. The estimated costs for rehabilitating the rapid rail system-wide controls range from $1.21 billion to $1.23 billion, between $29 and $35 million for light rail systems, and between $.29 and $.30 billion for the commuter rail systems. At the 75 percent funding level, the total costs from $1.8 billion to nearly $2.0 billion. The rapid rail system-wide control improvements would cost between $1.2 and $1.5 billion, between $34 and $52 million for light rail, and between $.37 billion and $.56 billion for commuter rail systems.

The cost for rehabilitating transit stations are illustrated in Figure 5.44. At the 50 percent level of funding, the costs range from $1.85 to $1.95 billion. The cost to rehabilitate the rapid rail systems range from $1.6 to $1.8 billion, $4 to $6 million for light rail systems and between $.19 and $.23 billion for commuter rail systems. At the 60 percent level of funding, the total station improvement costs range from $2.2 to $2.3 billion. The cost to rehabilitate the rapid rail stations range from $1.96 to $2.04 billion, between $4 and $7 million for light rail and between $.23 and $.25 billion for commuter rail. At the 75 percent funding level, the costs to rehabilitate the transit system stations range from $2.6 to $2.8 billion. The proposed improvements to the rapid rail stations range from $2.3 to $2.5 billion, between $12 and $14 million for light rail and between $.28 and $.35 billion for commuter rail systems.

The costs to rehabilitate the transit system structures are provided in Figure 5.45. At the 50 percent

FIGURE 5.44
COSTS FOR VARIOUS LEVELS OF FUNDING (STATIONS)



level of funding, the total costs for the structure improvements range from $1.39 to $1.46 billion. The costs for rehabilitating the rapid rail structures were estimated at $1.1 billion, $41 million for light rail structures and between $.30 and $.36 billion for commuter rail structures. At the 60 percent level of funding, the total costs to rehabilitate the transit structures were estimated at about $1.8 billion. The costs for rehabilitating the rapid rail structures range from $1.26 billion to $1.31 billion, about $41 million for light rail structures and between $.42 and $.47 billion for commuter rail structures. At the 75 percent level of funding, the total costs range from $2.3 to $2.5 billion for rehabilitating the transit system structures. The costs to

FIGURE 5.45
COSTS FOR VARIOUS LEVELS OF FUNDING (STRUCTURES)

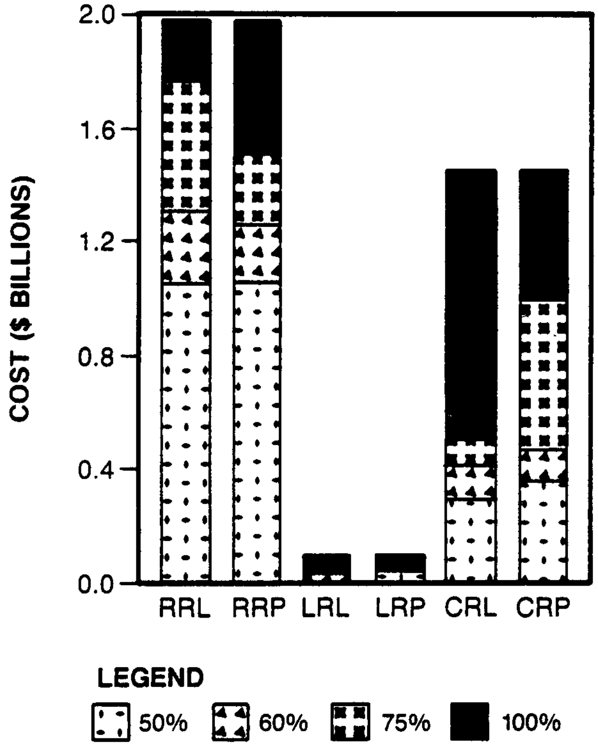
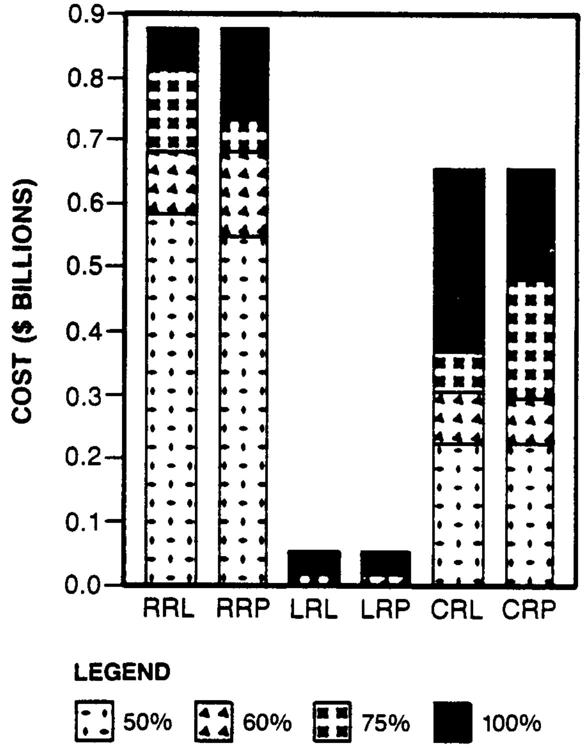


FIGURE 5.46
COSTS FOR VARIOUS LEVELS OF FUNDING (MAINTENANCE FACILITIES)



rehabilitate the rapid rail structures range from $1.5 to $1.8 billion, about $41 million for light rail structures and between $.5 and $1.0 billion for commuter rail structures.

The estimated cost for various levels of funding for the maintenance facilities are provided in Figure 5.46. At the 50 percent level of funding, the costs were estimated at about $.8 billion. The costs for rapid rail maintenance facility improvements range from $.55 to $.59 billion, between $1.0 and $19 million for light rail maintenance facilities and about $.23 billion for commuter rail maintenance facilities. At the 60 percent level of funding, the total costs for all maintenance facility improvements were estimated at about $1.0 billion. The rapid rail maintenance facility improvements were estimated at about $.68 billion, between $2.0 and $19 million for light rail maintenance facilities, and about $.3 billion for commuter rail systems. At the 75 percent level of funding, the total costs were estimated at about $1.2 billion. The proposed improvements to the rapid rail maintenance facilities were estimated to cost between $.7 and $.8 billion, between $18 and $24 million for light rail maintenance facilities and between $.37 and $.48 billion for commuter rail systems.

6.0 SOURCES OF LOCAL FINANCING FOR RAIL MODERNIZATION

A review was made of the 13 major rail systems to determine the sources of funds available and utilized by these systems for operating costs and capital improvements. The metropolitan areas served by these rail systems, and to a large extent responsible for a major portion of their financial support, were evaluated in terms of present policies and programs to support the transit system and the environment for introducing new programs to insure long term financial viability of the transit systems.

The rail systems, all publicly owned and operated, included the older established systems such as the NYCTA and the New York City commuter railroads (the LIRR and the Metro North) now consolidated under the MTA, Philadelphia's SEPTA, and Chicago's CTA, as well as the newer systems such as Washington's WMATA and San Francisco's BART. The systems range in size from San Diego's MTDB with a current operating and capital budget of $7.6 and $17.2 million (for San Diego Trolley, Inc.), respectively, to the MTA with $4.1 billion and $1.5 billion for annual operating and capital expenditures (1986).

The funds to maintain and operate the transit systems come from several sources. Direct transit system revenues (in most cases almost entirely from the fare-box) support portions of the system operating costs. The proportion of the total operating costs covered by direct system revenues (often referred to as the fare-box recovery ratio) ranges from a low of 22 percent in Pittsburgh's PAAC to a high of 75 percent for the Philadelphia-Southern New Jersey PATCO[1], followed closely by San Diego's MTDB with 72 percent.

The remainder of the operating costs (operating deficit) and all of the costs associated with capital improvements are provided by other sources, usually the local, state and federal governments. Most of the systems have relied heavily on the federal government for both operating and capital assistance; notable exceptions are the two fairly new western systems, BART and MTDB, which receive no federal operating support, and PATCO (owned by the Delaware River Port Authority). In terms of capital funding, all of the systems except PATH utilize federal funds, primarily from the UMTA Section 3 and 9 programs, but also through the Interstate Transfer provisions.

State funds for operating deficits are utilized by all the non-Port Authority supported systems, except MARTA, which is prevented from receiving such funds through the enabling legislation that established a local sales tax increment for transit support. State funds for capital improvements are used by all systems, again with the exception of PATH.

Local funds from city and from county governments or from dedicated local taxes are used by all of the systems except MTDB (which uses no local funds for either operating or capital purposes) and MBTA which uses local funds for operating support but not for capital programs.

In all of the transit systems there is a desire to secure long-term, reliable funding; some of the systems—most notably BART and MARTA—have dedicated taxes flowing to the systems. At the other end of the spectrum is the NJTC which has to rely on annual budget allocations in the New Jersey Department of Transportation (NJDOT) budget, where transit has to compete with other priorities on a yearly basis. It is clear that those cities with limited funding will have to be more aggressive in the future in capturing the benefits of transit through such mechanisms as benefit assessment districts and joint development.

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[1]PATCO and PATH are owned and supported by financially strong port authorities, and derive much of their funding from those organizations.

6.1 GENERAL REVENUE SOURCES

Transit system revenues are for the purposes of this discussion divided into "direct revenues"—fares, concessions, rentals and other income from the operation and management of the system and its capital facilities, and "indirect revenues"—revenue streams that may flow to the transit system as a designated recipient of a special assessment or tax increment or the like. The major proportion of the direct revenues in all the systems reviewed comes from the fares, with other sources such as concessions or investment income ranging from less than 1 percent (of total direct revenues) to a maximum of 14 percent (MTA).

The following listing includes most of the current sources of transit system direct revenues, other than fares:

- o Advertising (vehicles, stations/shelters).
- o Property rentals (including air rights).
- o Investment income (short-term use of funds).
- o Concessions.
- o Parking fees.

Indirect transit revenues are generally related to a tax or assessment levied on population groups or areas that benefit directly from the continued existence of the transit service being provided by the system. Such a levy or tax increment may be tied to a local or regional sales tax or may be based on square footage of office space within a "benefit assessment" area. Benefit assessment districts have provided important funding for new projects in several cities. They have considerable potential in financing rail modernization.

The second list includes potential sources of indirect revenues designated for use by a particular transit system, or possibly transportation/transit in general. These funds may be used to support operations or capital improvements:

- o Federal grants.
- o Appropriations from state and local general revenues.
- o Dedicated sales tax (local or regional).
- o Dedicated gasoline tax (local or regional).
- o Dedicated payroll tax (local or regional).
- o Dedicated excise tax (local or regional).
- o Transit benefit district assessment.
- o Tax increment financing.
- o Bridge/tunnel tolls.

In addition to the above listings of sources of revenues for transit systems, there are other ways of raising funds to meet the financial obligations of capital improvement projects. They include:

- o General obligation bonds.
- o Revenue bonds (supported by taxes or revenues).
- o Equipment leasing (including sale of depreciation allowance through the "Safe Harbor" provisions of the current Tax Act).
- o Joint development. The sharing of the cost of major new transit stations (primarily public areas) between the transit systems and private developers.
- o Equipment vendor financing.

The 13 transit systems reviewed in this study are now using, or have used in the past, most of the funding sources or mechanisms indicated above. The non-fare direct revenue sources are all generally utilized by all of the systems to a varying degree, depending on local conditions and market forces.

The potential for rental income is directly related to amount of space or facilities owned/controlled by the transit systems and the market for such space. The transit systems that derive the most rental income, such as MARTA, do so because they established a process to assure this potential revenue source was actively pursued. Concessions are an income source that should be examined closely for possible expansion. Other benefits, primarily security, can also be derived from such use. Parking fees can be charged if there is no free parking available, and if the total trip cost (fare plus parking) does not make transit use uneconomical.

Taxes and assessments designated for transportation/transit purposes or for a particular transit system constitute a legislated long-term reliable funding source of the type that is desired by many transit systems in the U.S. The Atlanta area was successful in 1971 in imposing a 1¢ sales tax in two counties, but only after a major public relations effort and political bargaining. (A previous effort just after MARTA was created failed.) The legislation establishing the tax has several conditions attached, including a limited life (10 years at the 1¢ level), fares to be frozen on the system for a certain period of time, and no access to state funds for operating or capital purposes. Notwithstanding the conditions placed on the tax, Atlanta and MARTA now have a secure financial basis.

Pennsylvania passed enabling legislation in 1985 permitting the establishment of "transportation development districts", in which special assessments may be made, benefitting the transit system. One of the first attempts to establish such a district is currently in litigation, and until the issue has been decided in the courts, this option will not be available to the Pennsylvania transit systems. Both SEPTA and PAAC are awaiting the outcome of the initial case.

Bonds are a common way of raising funds for capital projects, and have been used by the transit industry quite extensively.

Leasing as a means of acquiring new equipment without having to come up with the full purchase amount at one time has been used by most of the systems. Leasing has another attribute that makes it economically attractive to public entities such as transit operators; the tax laws do not permit public (non-profit) entities to take advantage of the depreciation and investment tax credits, so by leasing rather than purchasing, these benefits can remain with the legal owner of the equipment, who in turn can accept lower lease payments. The Safe Harbor provisions of the present tax code permit the outright sale of depreciation allowance by transit operators on equipment placed in service by 1988.

Vendor financing simply means that the transit system buys a piece of new equipment "on time" as one would a new car, eliminating the need to float bonds or borrow in other ways for major purchases. As the international competition in the transit equipment field increases, more and more of the major manufacturers and suppliers are willing to finance equipment purchases in this way.

Joint development is real estate development that is closely linked to public transportation services and station facilities. It relies on the market and locational advantages provided by transit to enhance the value of the development. Joint development provides financial support for transit agencies indirectly by increasing fare box revenues and directly through developer contributions and lease or other payments. Joint development has been successfully employed in old systems, such as Boston, New York and Philadelphia and in new systems such as Atlanta and Washington. In New York, developers have made major improvements in stations in return for higher density zoning. One developer has made a $25.6 million contribution to rebuilding a subway station. Two other are making improvements valued at $5 million or more each. WMATA estimates it will receive $3.5 million this year in joint development income. This represents the annual receipts for leases and other payments.

Joint development has only recently emerged as an important potential revenue source for transit systems. Successful implementation requires cooperation from local governments and developers as well as active support by the transit agency. The potential for increased revenues from joint development is considerable and should receive greater attention in the future.

6.2 HISTORICAL USE OF LOCAL, STATE AND FEDERAL FUNDS FOR OPERATING AND CAPITAL ASSISTANCE

Most of the major transit systems included in this analysis utilize a combination of local, state, and federal funding sources to offset deficits in the operating budget, and to support their capital improvement programs. Some of the systems can be considered to have a reasonably sound and secure financial base, through some source of dedicated funding stream, such as a local/regional sales tax increment. The BART system in the San Francisco Bay area, MARTA in Atlanta, and the New Orleans (RTA), all have sound financial bases created by a dedicated sales tax increment. The sales tax revenues are considered "local" funds, although they may be collected by the state and then returned to a local entity or directly to the transit operator. The revenue stream from a dedicated tax or assessment may be used in supporting both ongoing operations (to offset operating deficits), and to support capital improvement programs. In the latter case, a mechanism to enable the transit operator to make major payments toward purchase of equipment or construction of facilities, is to float bonds, guaranteed by and to be retired through the anticipated future revenues (for smaller periodic expenditures, it may be possible to simply raise the funds in commercial banks through tax anticipation notes).

The type of financial base provided by a dedicated tax increment or assessment would be the preferred approach to fiscal planning by all U.S. transit systems, but in many cases the local political climate has not been supportive of efforts to establish this funding mechanism. At the other end of the spectrum, without any year to year assurance of continued support of operations or capital improvements, are systems such as the NJTC operating, among other service, rail commuter lines in Northern New Jersey. NJTC's operations are funded through fare-box revenues, UMTA Section 9 funds, and state discretionary allocations. (There are no local transit funds in New Jersey.) The state allocations are based on the Governor's annual operating budget, taking into account anticipated fare-box revenues and estimates of federal assistance. While this type of discretionary state funding has been forthcoming, the funds are subject to the state legislative decision-making process where transit must compete against other priority needs. There have been many legislative efforts to secure a long-term dedicated source of transit funds in New Jersey, and one was successful—the Emergency Transportation Act, establishing a tax on income earned in New Jersey by residents of New York and Pennsylvania. However, this Act is still in litigation. (Such funds are intended for capital projects.)

Table 6.1 shows current use of local, state and federal funds for operating and capital assistance to the major rail transit systems serving the 12 major urban areas included in this analysis.

6.3 SUMMARY OF REVENUE SOURCES AVAILABLE TO EACH TRANSIT SYSTEM AREA

The following discussion summarizes the current strategies employed by the various metropolitan areas in providing the necessary financial basis for public transit services. The systems vary greatly in terms of fare-box recovery ratios and availability and amount of dedicated funding available.

- BOSTON (MBTA)

  The MBTA has been intensively engaged in the expansion of its system and the upgrading of its infrastructure since it inherited a limited and antiquated system at its founding in 1964. Over this period, the MBTA's capital program has implemented \$3.5 to \$4.0 billion of improvements to the existing physical plant and extensions to the rapid transit system as well as purchases of new buses, transit vehicles, and commuter rail equipment. As a result, substantial

TABLE 6.1

TRANSIT SYSTEM SOURCES OF FUNDS FOR CURRENT OPERATING AND CAPITAL EXPENDITURES
($ x Millions)

	OPERATIONS						CAPITAL PROGRAM				
				Source of Funds to Off-Set Deficit				Source of Funds			
Metro Area Transit System	Budget	Total Systems Revenues	Fare-Box Recovery	Federal	State	Local	Budget	Federal	State	Local	Comments
Boston MBTA	518.0	144.0	28%	24.0	250.0	100.0	240.0	110.0	130.0	0	
New York MTA	4,078.1	2,089.2	51%	107.8	176.2	1,061.6	1,470.0	435.0	0	148.0	Operating assist. from other sources as well, incl. TBTA, etc. Bal. of cap. funds from PA local bond issues, leases and vendor financing.
Philadelphia SEPTA	495.0	250.0	50%	32.0	115.0	98.0	128.0	100.0	20.0	8.0	
PATCO	18.5	13.9	75%	0	0	4.6	5.0	3.7	0	1.3	Local share from Delaware River Port Authority.
NY/NJ NJTC	225.0	121.6	54%	22.5	76.5	0	99.0	65.3	33.7	0	Additional 2% from non-operating revenues towards operating deficit.
PATH	120.8	74.7	62%	0.2	0	74.5	114.7	0	0	114.7	Local share from PA, NY & NJ operating revenues (operations) bond funds (capital).
Pittsburgh PAAC	18.4	4.0	22%	2.2	8.9	3.3	77.1	61.6	12.9	2.6	
Washington, D.C. WMATA	423.1	212.2	50%	18.5	0	192.4	365.0	292.0	0	73.0	Federal Capital funds from Stark Harris Act. 1985 data.
Chicago CTA	610.8	317.1	52%	32.0	80.0	181.7	180.3	138.8	32.5	9.0	
Cleveland RTA	127.0	38.2	30%	9.0	5.7	74.1	57.0	45.6	5.7	5.7	Local share of operating costs from sales taxes.
Atlanta MARTA	123.6	44.5	36%	7.1	0	72.0	287.9	132.4	0	155.5	
New Orleans RTA	65.8	31.0	47%	5.1	4.3	25.4	79.8	59.9	0	19.9	
San Francisco BART	163.9	86.7	50%	0	1.9	75.3	273.3	132.1	21.0	120.2	
San Diego [illegible]	7.6	5.5	72%	0	2.1	0	17.2	6.2	10.5	0	(+0.5 in lease arrangements toward capital budget.)

Note: Except as noted, capital and operating cost data is for 1986 (fiscal years vary from system to system).

increases in system safety and reliability and patronage by the public have been realized.

Federal dollars have amounted to 75-80 percent of all projects completed over the Authority's history. Bonds were issued for the local share. Chapter 637 of the Act of 1983 provided the MBTA with bonding authority to undertake a limited number of projects with 100 percent local funding for the first time. This Act provided $206 million in bonding authority for FY'84 and '85 as a vehicle for meeting the local share requirements for UMTA-funded projects as well as to permit some work to be undertaken outside the UMTA grant system. Chapter 811 of the Act of 1985 provided an additional $384 million in additional authorization for similar purposes. The MBTA operating budget assumes 10 percent of the cost of each bond, while the remaining 90 percent is covered by the faith and credit of the Commonwealth of Massachusetts.

In addition to UMTA funding, the MBTA has received funding from the Federal Railroad Administration (FRA) in the Southwest Corridor and South Station projects, both of which are to include AMTRAK facilities.

In addition to the traditional funding approaches detailed above, the MBTA has utilized other financial innovations for its capital needs. It is currently financing 50 new Green Line No. 7 cars through a vendor financing arrangement. Under this arrangement the Japanese manufacturer Hinki Sharyo will sell the vehicles to a consortium of investors who will in turn lease them to the Authority under a lease/purchase program. Chapter 811 described above permits state assistance for leasing agreements. The state will fund 90 percent of the lease cost with the MBTA assuming the remaining 10 percent.

The MBTA has been actively involved with Safe Harbor leasing of its buses and rail equipment since 1982. The Authority is only allowed to sell the tax credits associated with the local share of UMTA grants, but may sell credits amounting to the full purchase price when purchased with 100 percent local funds.

The MBTA received authorization under Chapter 811 to sell property to developers on the basis of considerations other than the relative costs proposed by competing bidders. The MBTA Board has recently approved a policy relative to development of MBTA properties and individual development proposals are currently being processed. The MBTA has recently begun to actively pursue joint development.

- NEW YORK (MTA)

The MTA system includes the NYCTA and the LIRR and Metro North commuter rail systems. NYCTA provides rapid transit service in the five boroughs. (Where possible, the evaluation focuses on the rapid transit element only.) The MTA acquired the stock of the LIRR in 1966, and LIRR became a subsidiary of MTA in 1980. The LIRR provides commuter passenger (and freight) rail service for New York City and Long Island. The Metro North Commuter Railroad Company was created in 1982 as a subsidiary of MTA to provide commuter rail service between New York City and suburban counties.

MTA has been the primary beneficiary of series of legislative tax initiatives on the state level. In 1980 the state passed legislation establishing a 2 percent tax on gross receipts of oil companies, with the revenues going to transit operators. The law was repealed in 1982 and replaced with a whole package of statewide, metropolitan region, and New York City taxes as follows:

- Sales Tax - a 1/4 of 1 percent increase in sales tax for the 12-county MTA region.
- Gross Receipts Tax on Petroleum - a 3/4 of 1 percent gross receipts tax on petroleum sales, (exclusive of home heating fuel).
- Unitary Tax on oil company's earnings.
- Long Line Tax - a 3/4 of 1 percent tax on gross earnings of the intrastate portion of interstate telecommunications.
- Capital Gains Tax - a 10 percent capital gains tax on the transfer of commercial and industrial property in New York City (directed exclusively to the NYCTA for its bus and subway systems).

In addition to the above taxes, and federal and state assistance, MTA receives funds toward transit operations from the Tri-Borough Bridge and Tunnel Authority (TBTA) and other sources.

With respect to the funding of rolling stock and fixed facilities the MTA has been one of the most innovative transit systems. It was one of the first to take advantage of Safe Harbor leasing and continues to use this on vendor financing as a means to supplement federal and state contributors.

New York has also successfully pursued joint development as a method for rehabilitating stations. New York has issued bonds to fund part of its current 5-year rehabilitation program. At this time, New York is actively considering a range of options for providing an assured source of funding for capital projects as well as developing an approach to prioritize these projects.

o PHILADELPHIA (SEPTA)

SEPTA was established in 1964 to provide public transportation service to the five county Philadelphia metropolitan area, covering about 2,200 square miles. SEPTA has used federal, state and local funding sources for its capital improvement program, and to supplement system revenues for operating costs. There are no dedicated taxes or other earmarked sources of transit funding in Philadelphia.[2]

Capital funding to date has similarly been dependent on federal, state and local (five counties) support. The state's contribution is set at 16 2/3 percent of the total project cost. Federal and local support have supplied the remainder.

The search for alternative funding mechanisms has focused on joint development and outright contributions by institutions and private businesses toward construction of new facilities (e.g., Temple University station improvements).

SEPTA's 5-year program (1981-85) totaling $900 million for "ongoing system modernization" is

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[2]Act 47, passed in 1985, provides enabling legislation to establish "transportation development districts" with a special assessment levy. The legislation is, however, being contested and is currently in court.

significantly in excess of what is anticipated to be available from federal and state sources. The additional $1.1 billion 5-year "Supplemental Program", deemed necessary by SEPTA to bring the region's rail system up to contemporary operating standards, does not appear fundable without major new legislative initiative establishing a new dedicated funding source for the system.

- PHILADELPHIA (PATCO)

PATCO operates the Philadelphia-Lindenwold High Speed Line, a modern commuter rail service connection into the suburban areas of Southern New Jersey, across the Delaware River from Philadelphia. PATCO is owned by the Delaware River Port Authority (DRPA) which also provides the necessary funding towards operating expenses (the system has a fare-box recovery of 75 percent), and the non-federal share of any capital improvements. No state or local contribution are currently involved. The DRPA funds come from bridge tolls on the several Delaware River crossings under the DRPA jurisdiction, and it is anticipated that this funding can be increased as necessary to address reasonable future funding requests.

- NEW YORK/NORTHERN NEW JERSEY (NJTC)

The NJTC was created in 1979 and currently operates commuter rail service in the Northern New Jersey area (among other mass transportation services).

The funding structure which supports NJTC's operating activities is derived from several sources. The state provides approximately 30 percent on a non-dedicated basis, while 54 percent is derived from the fare-box, 15 percent from UMTA funds, and 1 percent from miscellaneous sources. The state's funds are purely discretionary; NJTC's budget is submitted as part of NJDOT's budget, and therefore the transit funds are subject to the legislative decision-making process. NJTC is empowered to introduce legislation independently of NJDOT, provided a sponsor is found. New Jersey transit funds for capital expenditures derive from UMTA Section 3, Section 5, and Section 9 funds, various bonding programs, Interstate Transfer Funds, and a one time special arrangement known as TRANSPAC. Currently, NJTC is not receiving funds from the state for capital purposes, even though there is a provision for receipt of such funds.

There has been much legislative activity to establish a long-term secure funding source of transit in New Jersey but as of now there is no dedicated funding source in place. NJTC is currently exploring joint development of public transit facilities with private sector firms. The Meadowview Development Corporation has built a rail station, on an existing rail line, as part of a commercial development project. The corporation retains title to the station, but has turned station management over to NJTC.

- NEW YORK/NORTHERN NEW JERSEY (PATH)

PATH is a subsidiary of the Port Authority of New York and New Jersey, providing service in the metropolitan New York-New Jersey area, with connections to Manhattan.

PATH is supported financially by the Port Authority. All 100 percent of capital improvement funding comes from Port Authority bond funds, and the major portion of operating deficits are supported through Port Authority contributions (and operating revenues). A minor amount of federal funding is received from UMTA for training, research and development, and technical studies, but the reduction or elimination in federal transit support would have no appreciable effect on PATH operations.

Non-fare revenues come from parking, concessions and advertising, and amounted to 8 percent of total revenue (1986). PATH is currently negotiating a Safe Harbor lease for 95 new rail cars, to be placed in service by the end of 1986. The Port Authority owns and leases the World Trade Center in New York, a rather unique revenue source.

o PITTSBURGH (PAAC)

PAAC's fare-box recovery ratio is rather low (22 percent projected for 1986) and the operating deficit is currently funded through a combination of federal (15 percent), state (62 percent) and local (23 percent) contributions. The local operating assistance comes largely from Allegheny County's revenue sharing funds.

Capital improvements have been funded through a combination of federal (80 percent), state (16.6 percent), and local (3.4 percent) contributions. Of other potential sources of funds, PAAC has utilized Safe Harbor leasing but not to the extent of some on the other systems. Leasing arrangements have involved light rail vehicles, and PAAC also participated in Pennsylvania's state-wide bus pool lease program. Equipment vendor financing has not been used. Parking fees are not used (it is believed that the added cost for transit riders will render transit noncompetitive with the other modes). Income from concessions are minimal and advertising has been controlled for aesthetic reasons.

As an indication of the Port Authority's successful financial management, the Mellon Bank just renewed its $14 million line of credit. The Port Authority is looking towards a decision on Pennsylvania Act 47, and if favorable, may attempt to have a local transit development district created.

o WASHINGTON, D.C. (WMATA)

The planning, development and operation of the transit facilities serving the Washington, D.C. metropolitan area are funded from the combined resources of the U.S. Government, the State of Maryland, the Commonwealth of Virginia, the District of Columbia, the local participating jurisdictions, and the Authority's operations.

The original extensive federal funding was provided by authority of the National Capital Transportation Act of 1969 (Public Law 91143). This Act was subsequently amended on January 3, 1980 by Public Law 96-184 "The National Capital Transportation Amendment of 1979" which authorized an additional $1.7 billion for construction of the Metrorail system. WMATA has also received interstate transfer funds. The Authority has also obtained funding under certain agreements to cover debt service on its transit bond obligations.

In addition to the capital contributions provided to the Authority by the federal government and the participating jurisdictions, the Authority's revenues consist primarily of fare-box revenues from passengers and operating subsidy payment from UMTA under Section 9 and the participating jurisdictions. The balance of the Authority's budget is provided through operating subsidy payments from the participating jurisdictions. Funding of these subsidy payments is authorized by the participating jurisdictions through their budgeting processes.

WMATA has taken advantage of Safe Harbor leasing, with a total income (savings) of over $5 million in 1985 and $3.7 million in 1986. WMATA currently receives $3.5 million in joint development funds. This should increase in the future. WMATA does not have a dedicated source of funding.

- CHICAGO (CTA)

The CTA is one of four "service boards" (transit operating entities) under the jurisdiction of the RTA. CTA operates the Chicago rapid transit and bus systems. It receives all of its funding through the RTA, and the CTA budget has to be approved by the RTA board. CTA has a legislative mandate to maintain a fare-box recovery ratio of at least 50 percent.

CTA is currently provided a reasonably sound financial basis by a dedicated sales tax increment flowing to the RTA; 1¢ in the City of Chicago, 1/2¢ in Cook County, and 1/4¢ in the other five "collar" counties represented on the RTA. Eighty-five percent of the tax increment is distributed by the RTA on a formula basis. CTA gets the full amount of this 85 percent allocation of funds collected in Chicago and about 30 percent of the funds collected in Cook County.

The RTA recently initiated a study leading to the development of a long-range strategic plan for transit financing within the RTA jurisdictional area. The study has evaluated a range of new revenue options, including a dedicated gas tax, a dedicated corporate tax, an increase in the current sales tax increment in Cook County and the "collar" counties, and a doubling of the current sales tax increment across the board. The political acceptability of these and other revenue options are considered rather uncertain at this time.

A special downtown Chicago assessment district was previously established (to support major rehabilitation of the "Loop") but was never utilized.

CTA is currently the beneficiary of about $350 million in interstate transfer funds (handled through the City of Chicago, and not reflected in CTA or RTA budgets.)

- CLEVELAND (RTA)

The RTA was established in 1974 under the laws of Ohio, by resolution of the City of Cleveland, and Cuyahoga County. The RTA's area of jurisdiction is Cuyahoga County, and the Authority is authorized to levy a sales and use tax for transit purposes, including both capital improvement and operating expenditures, at the rate of 0.5 percent, 1 percent, or 1.5 percent if approved by a majority of the electors residing within the territorial boundaries of the Authority. Such a sales and use tax is in addition to the sales and use taxes levied by the State of Ohio and Cuyahoga County. On July 22, 1975, the voters of the County approved a 1 percent sales and use tax with no limit on its duration.

The Authority also has the power, under Section 306.40 of the Ohio Revised Code, to levy and collect both voted (after approval at an election) and unvoted ad valorem taxes on all the taxable property within the territorial boundaries of the Authority, in order to pay debt service on its bonds and notes issued in anticipation thereof.

The Authority is managed by a ten-member Board of Trustees and provides directly, or under contract, virtually all mass transportation within Cuyahoga County.

The sales tax, flowing directly to RTA, provides a long term reliable source of revenues, amounting to $76.7 million in 1985 (8 percent increase in 1984). RTA also receives federal and state operating assistance, but no local support (aside from the sales tax).

Capital improvement projects are funded through federal and state capital grants, with the local share made up from RTA bonds. (RTA is authorized to issue bonds, up to a debt limitation, based on the Authority's assessed value.)

- ATLANTA (MARTA)

MARTA was established in 1966. A referendum in 1971 (the second attempt) established a 1¢ sales tax in Fulton and DeKalb Counties, to support of transit development in those Counties. The legislation establishing the local option sales tax also provided that there be no state support for transit in the Counties electing to impose the tax. Accordingly, MARTA's financial base consists of fare-box revenues, proceeds from the sales tax, certain investment earnings and UMTA funds.

- NEW ORLEANS (RTA)

The RTA was created in 1979, but it was not until 1983 that the RTA assumed operating responsibility for the bus and streetcar transit service in New Orleans. (New Orleans was the last major city in the U.S. to transfer its transit operations to a public authority.) In 1982, and again in 1983, voters in New Orleans approved a 1¢ sales tax, with the proceeds to be shared by the City and the RTA. Again, in 1985, the voters were asked to approve a 1¢ sales tax, but this time exclusively for transit, and the tax was overwhelmingly approved, insuring long term stability for transit service in New Orleans. Proceeds from the 1¢ sales tax amounted to $39.6 million (1985) of which 67 percent or $26.7 million went to support transit operations and the rest toward capital projects and debt service.

RTA also receives a federal and state operating subsidy, but no state support towards capital improvement projects. Local share for capital projects are in part made up from the sales tax supplemented by local bond funds.

RTA is currently looking into equipment leasing and vendor financing, and expects to be able to advance one or more joint development projects in connection with the Riverfront Streetcar improvements. The Authority has rather unusual revenue source in the royalties from film and video rights, but none of the non-fare revenues are significant in the context of the overall budget.

- SAN FRANCISCO BAY AREA (BART)

The San Francisco Bay Area Rapid Transit District is a public agency created by the legislature of the State of California in 1957 and regulated by the San Francisco Bay Area Rapid Transit District Act, as amended.

The 1969 Legislature of the State of California authorized the District to impose a one-half percent transaction and use tax within the District and issue Sales Tax Revenue Bonds totaling $150 million. The state legislature later extended the tax to June 20, 1978 and authorized the District to issue bonds totaling $24 million to be used for operations. Payment of these Sales Tax Revenues Bonds was completed by June 30, 1978.

On September 30, 1977, the Governor signed legislation which extended the transactions and use tax indefinitely. The tax is collected and administered by the State Board of Equalization. Of the amounts available for distribution, 75 percent is allocated directly to BART and 25 percent is allocated by the Metropolitan Transportation Commission to the District, the City and County of San Francisco, and the Alameda-Contra Costa Transit District for transit services on the basis of regional priorities established by the Commission.

In October 1982, the District issued revenue bonds totaling $65 million to pay a portion of the cost of acquisition of 150 rail transit vehicles and related automatic train control equipment for use in the District's existing rapid transit system. The 1982 Bonds are special obligations of the District payable from and secured by a pledge of revenues, including certain sales tax revenues. 1986 revenues are projected to be $78.6 million from fares, with another $8.1 million from other sources, and a total income of $86.7 million and a fare-box recovery of a little less than 50 percent. There is no federal operating assistance, and the state contribution is only $1.9 million, with the balance coming from the property and sales taxes.

The capital improvement program for 1986 anticipates federal and state contributions from the fiscal guideway and STA programs. The local share of about 44 percent is made up of regional and BART funds, funds transferred from the operating accounts, and property tax revenues.

The Metropolitan Transportation Commission is sponsoring new legislation to increase the sales tax (SB-878), allowing the Counties to impose up to a maximum of 7¢ (present rates now vary between 6 and 7¢), with the proceeds going to transit and highways, at the option of the Counties. The imposition of this new tax increment would further improve BART's already sound financial position.

- SAN DIEGO (MTDB)

The MTDB manages the new light rail system in San Diego through its subsidiary corporation, San Diego Trolley, Inc., one of several operating transit companies under the MTDB. San Diego Transit, another MTDB operating subsidiary, was acquired by MTDB in 1985, with the MTDB from then on responsible for the provision of transit service on the regional routes.

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