ESTABLISHING AN ANALYTICAL FRAMEWORK TO EVALUATE TRACK MAINTENANCE MANAGEMENT POLICIES AT THE MBTA

by

Daniel B. Mesnick

B.A., Economics, Antioch College

(1979)

SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS OF THE

DEGREE OF

MASTER OF CITY PLANNING

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 1985

Signature of Author ____

Department of Urban Studies and Planning
May 17, 1985

Certified by ____

Ralph A. Gakenheimer
Thesis Supervisor

Accepted by ____

Phillip Clay
Graduate Committee Chair

DISCLAIMER

MISSING PAGE(S)

Page 93 is missing from the Library & Archives copies. This is the most complete version available.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

ESTABLISHING AN ANALYTICAL FRAMEWORK TO EVALUATE TRACK

MAINTENANCE MANAGEMENT POLICIES AT THE MBTA

by

DANIEL B. MESNICK

Submitted to the Department of Urban Studies and Planning on May 18, 1985 in partial fulfillment of the requirements for the Degree of Master of City Planning

ABSTRACT

The purpose of this thesis is to establish an analytical framework to evaluate heavy and light rail track maintenance management policies at the MBTA. A set of comprehensive track performance measures are proposed to provide management with an internal capability to determine where track defects per unit-mile are highest and establish minimum performance standards at the link, station, line, or system level. An optimal track equipment inventory and maintenance expenditure database design is proposed to facilitate component life-cycle costing and subsequent resource allocation for equipment, labor, and materials. In addition, an assessment of the institutional, organizational, and budgetary elements which contribute to track maintenance policy is included.

The database design, performance measures, and policy recommendations presented in this thesis are intended to complement existing and planned programs at the MBTA Engineering and Maintenance Department.

Further, implementation of these plans should assist Management in its ability to procure necessary future funding requirements, particularly in programmed maintenance areas.

Thesis Supervisor: Ralph A. Gakenheimer
Title : Professor of Urban Studies and Planning

Acknowledgements

The author is grateful to a great many individuals who donated their time, patience, and support to facilitate this research effort. Mr. Ralph Duvall, (Chief Engineer at the MBTA's Engineering & Maintenance (E & M) Department, approved my initial request for data and access to pertinent records. Without his blessing, the project would have been doomed.

Mr. James Rooney, Chief of Staff for Administration and Finance at the E & M Department, acted as an instrumental liaison to coordinate meetings with his staff and others. Further, his enthusiasm fueled my own. John McSweeney, Assistant Finance Officer, methodically responded to my every request for track program and maintenance control data. My friends at the Maintenance Control Center, including Mr. Paul Munchback Coordinator, and his staff, George Keller, Billy Shaw, Tom Sherlock, and Tom Boyd, patiently responded to my numerous interrogation sessions concerning the interpretation of defect reports. Mr. Tom Riley, Superintendant of Rail Engineering, provided valuable insight on track characteristics and standards.

In addition, I extend my deepest appreciation to my thesis advisor, Professor Ralph Gakenheimer of my own Department of Urban Studies and Planning, for his flexibility and constructive criticism over the past year. Carl Martland, of MIT's Center for Transportation Studies, and David Skinner of the Transportation Systems Center served as my Readers. Thanks to Carl for emphasizing the importance of simplicity in analytic style, and the need for management controls, operating plans and standards, standards, standards. David offered me a great deal of support in developing analytical performance measures.

Special thanks to Deena Mesnick-Siegel who provided valuable editing and superior support. A torrent of last-minute typing was accomplished by Marsha Orent and Penny Simpson.

To express my ultimate gratitude, of course, I would like to take this opportunity to thank my parents, Hilda and Sam Mesnick, who

encouraged me to live, at an early age, by this motto:

"The railroad yards are lovely
dark and deep;

But I have promises to keep
and many tracks to walk
before I sleep;

Before I sleep."

List of Tables

List of Figures

List of Exhibits

List of Appendices

INTRODUCTION

Background

A tremendous amount of public concern over the nation's emerging "Infrastructure Crisis" has recently been expressed. In Massachusetts alone a recent Joint Economic Committee sponsored study was performed by M.I.T. which concluded that the state needs $2.8 billion (in 1982 dollars) in additional revenues by the year 2000 to sustain, renew, and rebuild public transportation facilities, sewerage systems and water supply. (Polenske, et. al., 1983, p. 138). This estimate excludes the cost of day-to-day maintenance functions. Whether exaggerated or real, the infrastructure issue is an example of crisis-response management to freeze continued condition deterioration and assure public perception of adequate safety. Clearly, sound program maintenance (Markow, 1984, p.9) policies implemented at the beginning of the equipment life-style serve to improve component reliability, availability, and maintainability (Mesnick, Morrisey, 1982, p.149). Equally important, sound maintenance policy extends the useful operating life of a component, reducing the requisite capital replacement budget. Certain industries, such as commercial aviation, have developed and implemented sophisticated approaches to programmed maintenance using both measures of use-based and time-based performance measures, (Nowlan and Heap, 1978, p.89). Put another way, the operating environment dictates that any probability of catastrophic failure is unacceptable for safety reasons (loss of life translates to loss of market share which will damage firm profitability).

Why Maintenance

In the face of mounting instability over the amount and type of subsidization public transit properties will receive in the future, the importance of sound maintenance policy cannot be over stated. At the worst case federal funding outcome would anticipate the total elimination of UMTA Section Grants for capital (Section 3) and O&M (Section 9) Funds. As recently as 1984, UMTA sponsored the "New Start" Program which has fundamentally changed the selection criteria for the manner in which local transit proposals are financed. If passed, "New Start" will formalize the manner in which competing funding projects are judged. The formula specifies various population density, ridership, and socio-economic parameters to base a "Go" or "No Go" decision. Many, however, agree that the criteria are not actually objective, that they favor the more affluent cities which are willing to provide a greater percentage of the local capital for matching grants. Major UMTA awards of late have been to cities like Los Angeles (SCRTD) and Houston, (METRO) which, not coincidentally, were willing to sponsor a 50/50 local match, instead of the usual 20% local, 80% federal formula grant for capital programs. Few will deny that public transit properties face unprecedented challenges to operate under major budget restraint. In effect, UMTA has built a large equipment obsolescence into its formula program. Because transit properties were seduced into adopting a "throwing it away when it breaks" philosophy by the federal structure ; 80/20 for capital costs requires a whopping 30% less locally generated reserve than the 50/50 O&M formula grant. Hence, the apparent tenet of the present funding climate is particularly harsh on the oldest properties whose infrastructure is plagued by deferred maintenance and in dire need of rehabilitation.

Northeastern cities are being particularly discriminated against because of the new structure of funding programs, major budget constraints, and property tax ceiling imposed locally. The union of all those constraints adequately describes Boston's MBTA.

Most observers' discretionary mode choice is influenced by reliability, safety and cost. A recent demonstration program at Tri-Met in Portland, Oregon showed that passengers' perceptions about ride quality, cleanliness, aesthetics, noise, etc. are all attributes which influence modal choice. This thesis starts by asserting that efficient maintenance programs and budget allocation will be a key ingredient to future operations. Scarcer resources will directly translate to an increasing reliance on the existing infrastructure, rather than new construction.

HISTORY OF RAPID TRANSIT IN BOSTON

Boston's contemporary light and heavy rail rapid transit system represents a hybrid of interconnected lines once operated privately, for profit. Only since 1964, have the 79 cities and towns served by the MBTA been served by a public mass transit provider.

Boston's nineteenth century population swelled and land use intensified. The demographic reality of the day severely constrained personal mobility through the peninsula of Boston and its surrounding communities. A century before, the colonial legislature encouraged ferry service between Boston and Chelsea, to complement existing but sporadic oxcart service. In 1826, stagecoaches were first scheduled to provide service in and around Boston (MBTA, 1983, p. 7). Omnibusses evolved from stagecoaches, which were more efficient for passenger boarding and alighting. Ride quality was poor in the wooden-wheeled omnibus which travelled on cobblestone roads.

During the eighteen forties, the British had been experimenting with iron-inlaid rails in the cobblestone streets to support iron-wheeled coaches drawn by horses. Horsecars were introduced to Boston in 1855, (MBTA, 1983, p. 7). They were the modern predecessors to self-propelled electrically-driven vehicles which came to be known as streetcars. Horsecars offered smoother rides, less drag due to friction, and higher carrying capacity than the omnibus. Iron wheels on iron rails did, however, eventually degrade due to frictional railhead and side wear. Hence, it can be accurately ascertained that horsecar companies had the earliest experience with both construction and maintenance of transit track.

By 1887, 300 miles of track operated by over twenty distinct companies traversed Boston's narrow streets (MBTA, 1983, p. 8). A spaghetti of often redundant and competing lines confounded, rather than relieved, Boston's congestion. This prompted the Massachusetts General Court to merge these companies into a single system, known as the West End Street Railroad.

As a single, amalgamated carrier which was now in a monopolistic position, management of the new system sought to replace the archaic and expensive horse as a power source. Mr. Frank Sprague was selected to introduce his invention of the electric trolley to Boston. He did. Sprague strung overhead wires to connect Park Street with Cleveland Circle and Allston. Electric trolleys proved to be an instant success in Boston.

On September 1, 1897, the first subway in America opened from Boylston to Park Street, (MBTA, 1983, p. 8). Concurrently, the first segments of what is now the Orange Line were constructed on elevated trackage between Sullivan Square and Dudley Street Station, and opened in 1901 (MBTA, 1983, p. 8). Sullivan Square Yard was the largest transit facility in the world at that time. Three years later, in 1904, the first underwater transit tunnel was installed to provide trolley service below Boston Harbor and East Boston. Today's Blue Line is built on the former Boston, Revere Beach and Lynn Railroad right-of-way, which was a narrow gauge steam railroad that originated in East Boston and terminated in Lynn. Conversion of the railroad line on October 1, 1952, required adaptive reuse of a right-of-way built to narrow gauge railroad specifications, rather than the 4' 8 1/2" standard gauge used by transit. [Extensive re-alignment of right-of-way grade weight and level were performed for the transit conversion project].

Definition of Track Construction, Renewal and Maintenance

The definition of transit track construction is clearcut; it is defined as the act of building or extending new track where none previously existed. An unambiguous distinction between track renewal, rehabilitation, and major maintenance programs may, however, be difficult. For purposes of consistency, the author will adopt the definition used by Cataldi and Elkaim, 1980:

Selective [Spot] Maintenance

> Selective maintenance involves the intermittent and/or periodic replacement or repair of only those track structure components (rails, ties, fasteners, ballast, etc.) that are defective or failing. As a result, there may be considerable variation in the age condition, and performance of the various component types and individual components in a given section of track.

Track Renewal

> Track renewal, which is also referred to as out-of-face renewal, consists of completely rebuilding the track structure as a single continuous process that involves renewing and/or adjusting all of the track structure components in a given section of track in a scheduled period of time in which the section is closed to traffic. Following the initial rebuilding process, such a track section is customarily given only light section gang or basic maintenance for perhaps 15, 25 or more years (the length of the period depending upon track structure, traffic and environmental conditions) until it is again rebuilt under the track renewal method.

To add to the working definition, the reader should be made aware that the definitions presented above were developed expressly for the mainline railroad operating environment. At least two modifications are in order. First, transit track renewal may be performed during revenue hours when trains continue to run over a single track while the parallel track is renewed while out-of-service. Some transit properties, such as Chicago Transit Authority (CTA), have devised a method of installing temporary switches before and after a double track mainline. The track to be renewed is worked on while revenue-trains from both directions proceed through the bottleneck. This practice is commonplace when two conditions exist: 1) Revenue-operations never cease, and 2) passenger volumes dictate that the cost of providing alternative bus shuttle services and closing down the link entirely for renewal, outweigh the cost of passenger delays and lower productivity during the construction period due to single track reconstruction. According to Mr. Bill Stead, Director of MBTA Operations, a single track renewal effort, for each direction was considered for upcoming major new renewal programs, but rejected because the contractor works much faster when both tracks are renewed simultaneously by his machinery and equipment.

MBTA Line Construction and Rehabilitation

MBTA track quality today is a composite function of maintenance, and capital investment decisions of the past.

Much of the theoretical basis for this statement is articulated in a parallel publication, "Maintenance Techniques for Road Surfacings."

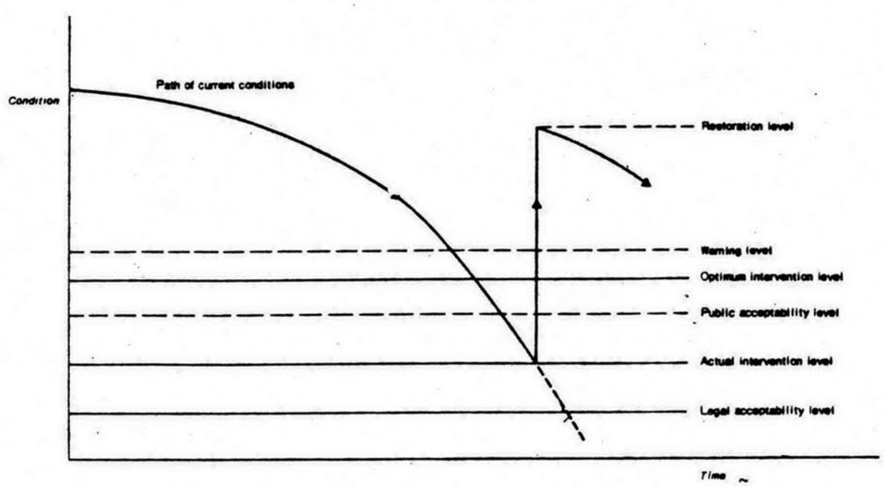
A classic engineering condition deterioration function is shown which plots condition (X-axis) over time (Y-axis). Figure 1-1 shows optimum, acceptable, and legal minimum intervention level for highway maintenance. This generic methodology is transferrable to transit track applications. In lieu of life-cycle maintenance and capital investment data it is important to understand at which point along the deterioration function a given track can be categorized. Historical intervention levels can be carefully deduced from an account of operator actions implemented by time and location.

Figure 1-2 presents an analytical model for the selection of optimal maintenance fully based on maintenance cycles plotted over time. To understand track mechanical and electrical condition for any specified link, this chapter provides a lineage of original construction dates and a chronology of master rehabilitations conducted in-house or with contractor support. Information contained in the MBTA history is intended to provide a brief overview from an institutional perspective. Construction rebuild dates are designed to complement the former narrative, at a greater level of detail and precision. This chapter is meant to provide an input into the analytical framework which follows.

In general, MBTA truck construction history is documented in "Rapid Transit Boston" published by the Boston Street Railway Association

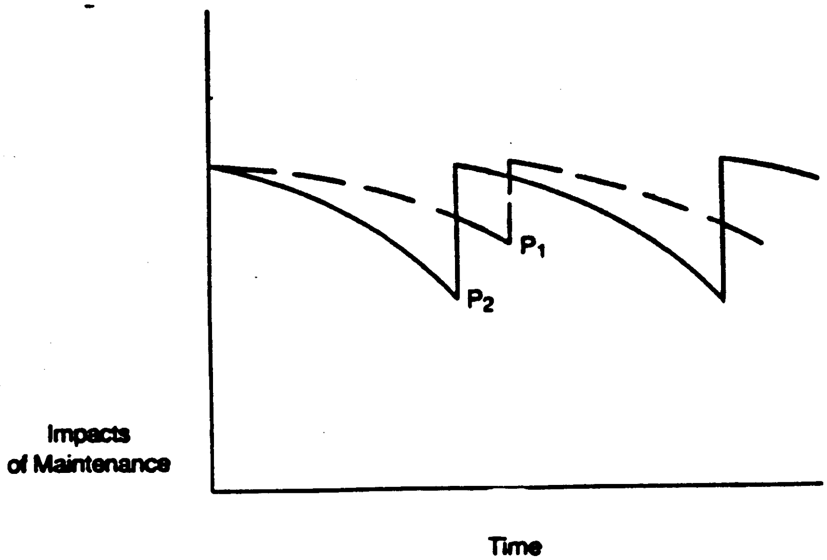
Figure 1-1

RELATIONSHIP BETWEEN DIFFERENT DEFICIENCY AND INTERVENTION LEVELS
(The levels as shown are not necessarily in their correct relative positions)

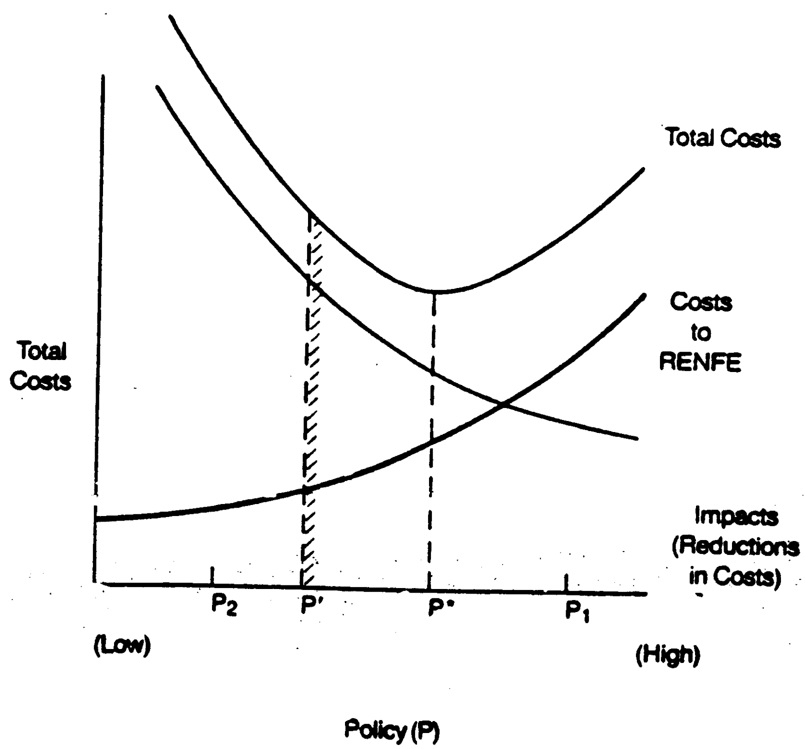


Source: Maintenance Techniques for Road Surfacings:. . ., 1978

Figure 1-2



Impacts of Two Maintenance Policies (P)



Selection of Optimal Maintenance Policy

Source: Markow, 1984

(1971) transit network route maps compiled for a series of developmental dates from 1897 - 1964, and "A Chronicle of the Boston Transit System." Data extrapolated from these references was confirmed by Mr. John Carre, Senior Program Management Officer at the MBTA Construction Directorate. Mr. Carre was also consulted concerning his knowledge of past major rehabilitation programs.

Mr. Carre offers the unique perspective gained by working for both the E & M and Construction Divisions at critical periods. The following chronology is presented as a single synthesis including both construction and rehabilitation activities by line rather than by date or action systemwide. This format will facilitate model input and complement data base construction. The reader is asked to make note of the fact that track which extends beyond the studies Cordon area is excluded for purposes of brevity. Similarly, any lines which once, but no longer, provide renevue-service, such as the abandoned Atlantic Avenue elevated structure, are irrelevant to this study.

ORANGE LINE: CHRONOLOGY OF TRACK CONSTRUCTION & RENEWAL ACTIVITIES

TABLE 2-1

CONS= Construction; REN = Renew

ACTION	STUDY LOCATION	LOCATION CODE	COMPLETION DATE	DESCRIPTION	PERFORMED BY
CONS	No. Station-Dudley Street		6/10/1901	Portion of present-day Orange Line links between No. Station to Haymarket and Boylston/Essex, Dover, Northampton and Dudley opened	Boston Transportation Committee(BTC)
CONS	Washington St. Tunnel opened		11/30/1908	Washington Street Tunnel connected to elevated structure at both North and South Portals - includes current State Street Station, Washington and Essex	BTC
CONS	Dudley-Forest Hills Elevated		10/22/1909	Forest Hills Orange Line Extension opened including Egleston Station	Boston Elevated Railway(BERY)
CONS	Green St.opened		9/11/1912	Green St. Station opened on the elevated	BERY
CONS	Haymarket-North Extension opened		4/7/1975	New line segment/row opened from Haymarket-North Station to Community College and the New Sullivan Square Station	Perini Construction
CONS	Wellington Station		9/6/1975	Link from Sullivan Square Station to Wellington on the relocated Orange Line opens for revenue operations	Perini/White (Mystic Bridge)
CONS	Malden Center		12/6/1975	Wellington-Malden Ctr. opened for operation	Perini
CONS	Oak Grove opened		3/19/1977	Link between Malden Ctr. and Oak Grove opened	Perini

RED LINE: CHRONOLOGY OF TRACK CONSTRUCTION & RENEWAL ACTIVITIES

TABLE 2-2

CONS = Construction; REN = Renew

ACTION	STUDY LOCATION	LOCATION CODE	COMPLETION DATE	DESCRIPTION	PERFORMED BY
CONS	Cambridge Subway opened		3/23/1912	Cambridge Subway construction completed including Harvard Square Station, Central, Kendall and Park Street.	
CONS	Dorchester Tunnel opened (Phase 1)		4/4/1915	Tunnel between Park Street and Washington Street opened.	
CONS	Dorchester Tunnel (Phase 2)		12/3/1916	Dorchester Tunnel Segment from Washington Street to South Station opened.	
CONS	Dorchester Tunnel (Phase 3)		12/15/1917	Dorchester Tunnel between South Station and Broadway opened.	
CONS	Dorchester Tunnel (Phase 4)		6/29/1918	Broadway to Andrew links of tunnel opened.	
CONS	Dorchester Rapid Transit Extension(Phase 5)		11/5/1927	Andrew Square to Fields Corner opened.	
	Dorchester Rapid Transit Extension(Phase 6)		9/1/1928	Fields Corner to Ashmont opened.	
	Charles Street Station		2/27/1932	Charles Street Station opened on Cambridge-Dorchester Rapid Transit Line	Dept. of Public Utilities
CONS/REN	Dover Street Yards		11/21/69	MBTA purchases Dover Street Yards of Penn Central RR for Red Line Shop Area	
CONS/REN					

RED LINE: CHRONOLOGY OF TRACK CONSTRUCTION & RENEWAL ACTIVITIES

TABLE 2-2
(cont'd)

CON = Construction; REN = Renew

ACTION	STUDY LOCATION	LOCATION CODE	COMPLETION DATE	DESCRIPTION	PERFORMED BY
CONS/REN	South Shore Rapid Transit Line		9/1/1971	South Shore Line opened at Interchange north of Columbia Station to Quincy Ctr. via former Penn Central railway including Neponset Bridge, No. Quincy Station, Wollaston and Quincy Ctr. Station.	
CONS	Cabot Yards		6/24/1974	Cabot Transportation Ctr. with Yards and Shops open.	MBTA
CONS	Harvard/Brattle Station		1979	Harvard/Brattle Station opened and erected as temporary facility.	
CONS	Harvard-Holyoke		1981	Harvard-Holyoke Station opened.	

BLUE LINE: CHRONOLOGY OF TRACK CONSTRUCTION & RENEWAL ACTIVITIES

TABLE 2-3

CON = Construction; REN = Renew

ACTION	STUDY LOCATION	LOCATION CODE	COMPLETION DATE	DESCRIPTION	PERFORMED BY
CONS	East Boston Tunnel		12/30/1904	First aquatic tunnel,(used originally by trolleys), built by BTC opened under Boston Harbor connecting E. Boston with the city from Maverick Square to Scollay Square (now Gov't Ctr.)	Boston Transportation Committee(BTC)
CONS	East Boston Tunnel Extension		3/18/1916	Extension of tunnel from Scollay Square to Bowdoin Square Station	BTC
CONS	Maverick Square Station		1924	Maverick Square Station Loop and Shops opened	Boston Transit Department (BTD)
REN	Rapid Transit Conversion		4/21/1924	Street or tracks converted to Rapid Transit (3rd rail operation) by adding high station platforms	BTD ?
SERVICE DISCONTINUED	Entire Line		1/27/1940	Boston, Revere Beach and Lynn narrow gauge steam railroad ceases operations	Boston, Revere Beach, & Lynn RR (B,RB,& L RR)
CONS/ REN	East Boston Extension		1/5/1952	Old Boston, Revere Beach & Lynn RR retracked for 3rd rail transit operations. Stations: Airport, Wood Island Pk, Orient Heights	BTD/MTA (Metropolitan Transit Authority)
CON/REN	Revere Extension (Phase 1)		4/21/1952	Orient Heights to Suffolk Downs link opened.	BTD/MTA
CON/REN	Revere Extension		1/19/1954	Orient Heights to Wonderland Station reconstruction/opening	(Note: source date discrepancy)

GREEN LINE: CHRONOLOGY OF TRACK CONSTRUCTION & RENEWAL ACTIVITIES

TABLE 2-4

CONS = Construction; REN = Renew

ACTION	STUDY LOCATION	LOCATION CODE	COMPLETION DATE	DESCRIPTION	PERFORMED BY
GONS	Tremont Street-Public Garden-Park Street		9/1/1897	First Subway for streetcars opened	Boston Elevated Railway(BERY) and Boston Transportation Committee(BTC)
CONS	Tremont Street-Pleasant St.-(Broadway)-Park Street		10/1/1897	Subway continued to Pleasant Street	BERY/BTC
CONS	Tremont Street Subway-North Station-Park St. Station (Section 3)		9/3/1898	Portion of line from North Station to Park Street opened including Haymarket, Adams Square - Scollay Square Station (now Gov't Ctr.)	BERY
CONS	Canal Street opened		10/23/1910	Canal Street surface pre-payment Station	
CONS	Lechmere Viaduct		6/1/1912	Lechmere Viaduct opened from Tremont St. Subway to Lechmere via North Station and Science Park West	BERY
CONS	Boylston Street Subway opened		10/3/1914	Public Garden to Kenmore Square opened including Arlington St., Copley Station, and Auditorium	BTC
CONS	Massachusetts Avenue Sta.		10/29/1919	Mass. Ave. Station opened (now Auditorium) on Green Line's Boylston Subway	BTC

GREEN LINE CHRONOLOGY OF TRACK CONSTRUCTION & RENEWAL ACTIVITIES

TABLE 2-4 (dont'd)

CONS= Construction; REN = Renew

ACTION	STUDY LOCATION	LOCATION CODE	COMPLETION DATE	DESCRIPTION	PERFORMED BY
CONS	Arlington Street Subway		11/13/1921	Arlington St. Station opened-Boylston Street Subway	BTC
CONS	Kenmore Extension		10/23/1932	Boylston St. Subway extended replacing Kenmore Station from surface to subway, lines built diverting at Kenmore to Beacon Street at St. Mary's Portal and Commonwealth Avenue at Blandford Street Portal	Boston Transit Department (BTD)
REN	Tremont St. Subway-Park St.		12/5/1936	Park Street Station enlarged on Upper Level including a new northbound platform	BTD
CONS	Huntington Avenue Subway		2/16/1941	Huntington Avenue Subway opened including Prudential and Symphony Station	BTD
NAME CHANGE	Massachusetts Avenue Station redesignated		2/18/1965	Old name "Mass. Ave. Station" changed to "Auditorium" Station	Metropolitan Transit Authority (MTA)
CONS	Science Park Station		8/20/1955	Science Park Station opened on Lechmere Viaduct	
REN	Huntington Avenue to Brigham Circle		1971	Remove track, excavate 8", ballast, new ties	E & M Construction
REN	Commonwealth Avenue Branch		1/31/1981	Commonwealth Ave. Branch re-opened after major rehabilitation	

THE MBTA ORGANIZATION TODAY

At the MBTA today, administration and control of track function is accomplished through the Operations and Construction Directorates while funds for maintenance and new construction are appropriated through the budget office. For a complete description of the budgetary procurement and allocations process, see the Budget Section of this chapter. All maintenance activities are managed by the Engineering and Maintenance (E & M) Department within the Operating Directorate. Mr. Ralph Duvall holds the top seat, Chief Engineer, at the E & M Department.

New track construction is conducted through contractors and administered by the Construction Directorate. See the section on the Five-Year Plan in this chapter for a schedule of programs, cost, and location, by program year. Projects managed by the Construction Directorate are in large part autonomous from all other directorates and receive eighty percent UMTA formula grants and twenty percent local funds. The Construction Directorate does, however, submit an annual budget proposal by element for its twenty percent local portion of the matching grant.

The E & M department also submits an annual budget proposal, element by element, but its formula grant is only fifty percent federally funded (UMTA) and a fifty percent local share for O & M. Exceptions do exist, including the one million dollar elevated structure dedicated funds and the two million dollar FY 1984/1985 Special Trackwork Program Funds, generated from a separate state budget source (See Budget Section).

Function of E & M Department

The E & M Department is responsible for system-wide track maintenance, design, and administration. It is now comprised of three departments: Maintenance of Way (MoW), Building-Structures, and Power and Signals; each of these departments were once separate and autonomous entities from each other at the MBTA. A fourth department was created to take care of administration and finance for the three operating departments (see Exhibit 3-1).

At the division level, MoW is responsible for upkeep of all surface lines, rapid transit lines, equipment, yards and contract services. The Power and Signal department handles signals and communications equipment (telephones, radios, beepers), power engineering, power transmission and distribution for catenary and third rail operations, and substations and equipment. Finally, the Building and Structures division has a staff of twenty-six employees in the planning and drawing room as well as labor representatives from a variety of crafts including electricians, carpenters, machinists, pipefitters, plumbers, asbestos workers, and others.

In August, 1979, the E & M Department's Maintenance Control Center opened. Located at 500 Arborway near Forest Hills Station, the Center serves as a twenty-four hour telephone dispatch center for all reported problems systemwide. Prior to August, 1979 the Center was only open eight-hours per day, with calls during other hours sent directly to the appropriate division. The center receives approximately 110 calls per day, or nearly 40,000 calls per year. At the present time, all records, or defect reports (See Exhibit 3-2) are maintained manually.

Exhibit 3-1

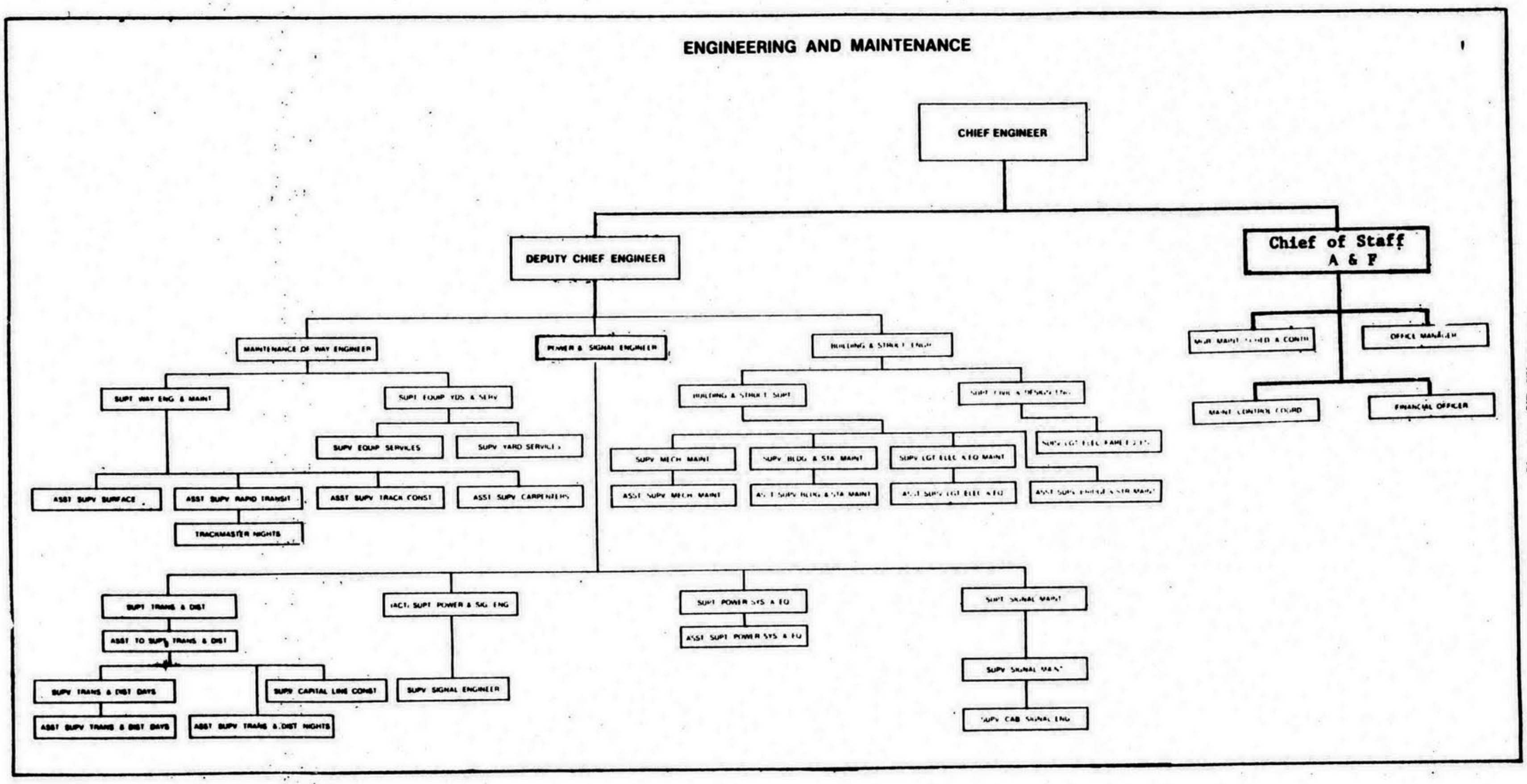

ENGINEERING AND MAINTENANCE
CHIEF ENGINEER
DEPUTY CHIEF ENGINEER
Chief of Staff A & F
MAINTENANCE OF WAY ENGINEER
POWER & SIGNAL ENGINEER
OFFICE MANAGER
MAINT CONTROL COORD
FINANCIAL OFFICER
SUPT WAY ENG & MAINT
SUPT EQUIP YDS & SERV
SUPV EQUIP SERVICES
BUILDING & STRUCT SUPT
SUPV MECH MAINT
SUPV BLDG & STA MAINT
SUPV LGT ELEC & EQ MAINT
ASST SUPV SURFACE
ASST SUPV RAPID TRANSIT
ASST SUPV TRACK CONST
ASST SUPV CARPENTERS
ASST SUPV MECH MAINT
TRACKMASTER NIGHTS
SUPT TRANS & DIST
(ACT) SUPT POWER & SIG ENG
SUPT POWER SYS & EQ
ASST SUPT POWER SYS & EQ
SUPT SIGNAL MAINT
ASST TO SUPT TRANS & DIST
SUPV TRANS & DIST DAYS
SUPV CAPITAL LINE CONST
SUPV SIGNAL ENGINEER
ASST SUPV TRANS & DIST DAYS
ASST SUPV TRANS & DIST NIGHTS
SUPV CAB SIGNAL ENG

Exhibit 3-2

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY — ENGINEERING—MAINTENANCE DEPT. **DEFECT REPORT**	(1) CONTROL NUMBER № 97005
(5) EMERGENCY CALL ☐ SERVICE WORK ☐	(2) DATE / (3) TIME
(6) LOCATION	(4) REPORTED BY / TEL #
(7) REPORT ABOUT	(10) WORK ACCOMPLISHED
	(11) WORK STARTED (DATE & TIME)
(8) CALL RECEIVED BY:	(12) WORK COMPLETED (DATE & TIME)
(9) CALL REPORTED TO: ENG. - 206	(13) SUPERVISORS SIGNATURE

Source: MBTA aintenance Control Center

Exhibit 3-3

N. R. Callahan
Supt. Equipment, Yards & Services

From: W. H. Bregoli, Jr.
Maintenance of Way Engineer

BAY TRANSPORTATION AUTHORITY

Date: August 20, 1982

Re: Track Defect Reporting Procedure

The attached memo dated August 18, 1982 from Ralph L. Duvall describes the procedure which all personnel will take for reporting all track related speed restrictions and crossovers or switches out of service.

Effective immediately, this procedure will be followed and any speed restriction or switch or crossover out of service, now in existence, will be reported in the described fashion to the Message Center. The same procedure is to be followed immediately after a speed restriction is removed or a crossover switch is put back in service. It will be in effect regardless of the time of day, or day of the week, which the restriction is required.

Please ensure that all personnel are aware of this directive.

W. H. Bregoli, Jr.
Maintenance of Way Engineer

WHB:mtd

Exhibit 3-3
(Cont'd)

To: W. H. Bregolf, Jr.
B. E. Harris
P. Munchback

From: Ralph L. Duvall

BAY TRANSPORTATION AUTHORITY

Date: August 18, 1982

RECEIVED
AUG 19 1982
Maintenance of Way Engineer

The following directive will outline the procedure which will be followed when either restricting or taking out of service any portion of the track or signal system. The responsible track section foreman or line signal inspector will notify the Maintenance Control Center when track speed restrictions are required or when it is necessary to restrict the use of crossovers, tracks switches, trip stops, signals, etc.

The Maintenance Control Center will be responsible for coordinating with the various Divisions within our Department to ensure that slow lights, speed restriction signs, resume speed signs, etc., are installed in a timely fashion in support of the action taken by the responsible line supervisor. They will also be responsible for notifying Transportation of the action taken by our Department. A current record will be maintained by the Maintenance Control Center for all such actions taken and will be noted on a blackboard located in the Control Center for use by all of us. They will also be responsible for the removal of speed restrictions and restoration of that portion of the railroad which has been taken out of service.

It is understood that from time to time, for safety reasons, any management supervisor may require that a portion of the system be either restricted or taken out of service, however, with the understanding that our procedure will be the same as that outlined above with all coordination taking place through the Maintenance Control Center.

Ralph L. Duvall
Chief Engineer

RLD:mc
cc: M. J. Foley
J. J. White

Hence, trend-line or statistical performance measurement is difficult. Further, low priority calls may get lost in the confusion.

About sixty percent of all incident calls require a crisis-response. The others are confirmed and distributed to the appropriate division for action. A variety of individuals generate incident reports, for which a defect report is filled out. They are: trackwalkers, management, dispatchers and inspectors, and the Communications Department.

Dispatchers are trained to identify particular reported symptoms and judge the priority for which calls must be responded to. A fire on a train or person under train is an emergency priority, Code One call. A set of procedures is followed to dispatch such a call including notification of policy to fire departments as well as responsible MBTA management and staff. A code two describes some kind of maintenance action to be taken, while code 3 corresponds with acts of vandalism. Each code has a specific set of formal procedures to be followed (see memo, "Track Defect Reporting Procedure, Exhibit 3-3).

A defect slip is made out in triplicate for each incident report. The slip identifies who filled out the card, where the incident occurred, what the reported problem is, and who was sent to the job. On the right side of the slip, the reader will note a blank block entitled "Work Accomplished." Unfortunately, the department rarely bothers to fill out this section. Hence the solution is generally a matter of pure conjecture. The reason for this problem is a lack of communication between those actually doing the work and those recording it. The pink slip of a defect report is sent to the responsible division. Until the "Work Accomplished" section is completed, the incident is theoretically an "Open" call. Although in practice the system does not function (Table 3-1).

TABLE 3-1

TRACK DEFECT REPORT INCIDENT CODES

Code	Description of Reported Condition
01	Track-related derailments
02	Wheels riding high
03	Insulation joint failure
04	C - bond or signal bond or ground bond
05	Third rail alignment, fracture or post
06	Broken thermo joint weld
07	Gap or pull-apart in joint
08	Broken bar
09	Broken, fractured, or cracked rail
10	Bolts broken, loose or missing
11	Switch point out of alignment
12	Switch malfunction in automatic mode
13	Switch tie rod bent or out of alignment
14	Switch frog worn
15	Rail heat wear
16	Rail gouged, chipped, or corrugated
17	Rail side wear
18	Heat Kink
19	Tamping needed
20	Cross level
21	Rail loose or moving
22	Broken anchor
23	Spike Corroded or loose
24	Tie rotted, split, or spike-killed
25	Tie burned
26	Tie place worn or moved

Road Department: Function and Operation

Nighttime Track Maintenance Organization

The Road Department is actually a subdivision of Engineering and Maintenance (E & M) Department Field Personnel (see organizational chart). This group is responsible for all heavy track and light track repair activities. Systemwide, most heavy repair or selective maintenance, is conducted during non-revenue hours. From after twelve midnight, when the last revenue-train returns to its homeyard, until revenue service commences at approximately five a.m., track gangs may begin to "set-up" by dispersing replacement materials and equipment at around nine-thirty p.m., but generally do not disrupt Transportation Department operations.

Track gangs work seven nights per week. The number of gangs working simultaneously on a given shift varies with the workload and requirements of each job. According to Mr. Paul Hagar, nightime superintendent of the Road Crew Department, there are five to six crews in the field on any given night. Approximately one hundred track laborers work the night shift from eleven p.m. to seven a.m. Sixty-two of them were hired July 31, 1984 to begin work on the new two million dollar "Special Track-Work Program." Their employment is directly tied to the earmarked special track program. If these funds are not renewed in the next fiscal year, it appears the need for these employees will diminisn but they will be retained. Although many of the new laborers were hired as temporary help, they will be converted to full-time employees after ten months of continuous employment.

The author, along with two other spectators, were given the opportunity to witness a series of track gangs in action during the night shift. At Wellington Yards, the author observed a switch frog being changed out.

To change out a single switch frog required a large crew consisting of a cutter (to cut through old rail), a welder(to weld new rail in-place and match with the old rail), a grinder (to burnish contact-surface welds) eight laborers, one iron worker, one crane operator and one section f reman. On-site equipment included a flat car for materials which housed an inoperable boom mounted on its rear-end, a second frame-only work car, and a gantry crane. All personnel were represented by Union Locals 589 and Local 4, with the exception of the steelworkers, who were members of Local A.

The tour then proceeded to Northampton Station on the elevated structure. A crew was hard at work replacing crossties and guard beams. The crew consisted of several carpenters (Local 324), one crane operator to lift each 600 pound tie in and out of place, and a foreman. Each tie on the elevated structure which is located on curved track is customized for a special superelevation at the lumber mill. They are meticulously placed on the structure using sequential numbers to indicate tie-order during placement.

At Savin Hill Station, a spot tamper was operating on its own power but not functioning as a tamper. When the complex piece of machinery is in operation, however, a crew of three to four laborers including a foreman and skilled operator can average approximately two thousand feet of lined and tamped track per shift. Spot tampers are incapable of working switches which must still be tamped by hand.

The author next took a ride on the inaugural run of a new work car equipped with a winch and boom in the rear. That evening a special crew consisted of three members of the Road Department and four Transportation Department personnel, who were learning to operate the new car.

The group tour ended at Copley Junction on the Green Line; where a sump pump station was seen and a pantograph crew, from the Power and Signal Department, adjusted overhead power lines and land track power cables. There has been a recent program (FY 1981/1982) to improve the reliability of subway sump pumps. (33 pump rooms, 75 pumps). This program is critical to increasing track performance by minimizing water-related track deterioration.

Joint Crew

Several specialized crew types were not observed during the tour. During the night shift, these included the Joint Crew. This crew operates system-wide to change-out, clean, and replace malfunctioning insulation joints. The crew is on duty nightly between midnight and seven in the morning. Once detected, usually by a trackwalker, the line supervisor uses his daily log to dispatch the Joint Crew. In a given shift, the crew is given a system-wide itinerary of joint failures, based on the "Daily Trouble Log" compiled by the daytime and nighttime section Foreman. Much of the failure identification for this trouble log is provided by trackwalker's visual inspection.

In general, the most severe joint failures are responded to first by the Joint Crew. The crew uses a "high-railer" for welding equipment and an inventory of new joint materials. A high-railer is a large van-type truck capable of negotiating both roadways and rails; once on the rails, the high-railer is a moving warehouse of equipment and materials necessary to fix iron and insulation rail joints. Depending on the nature of the jobs to be done that night, the crew consists of three to four men; a foreman, an operator (driver), a burner and welder (to remove corroded bolts or the new type of joint bolts), and two laborers (Local 589). The crew makes service stops between the hours of 1:00 A.M. and 5:30 A.M. Insulation joints are cleaned completely of slivers, debris, and foreign matter, then re-assembled with a new insulation end-post, made of wood or plastic. On a good night, the crew can change-out and reassemble three joints per shift.

In addition to those night crews operated by the Road Department, a variety of crews during non-revenue hours represented by the Power and Signal division, Building and Structures division, and Construction Directorate supervised contractor gangs involved in track renewal programs. At the date of this writing, an assortment of J.F. White contractor-supplied gangs are working on renewing track on the Park Street outer loop. Coordination of track gang work locations is developed by the road department night Supervisor and his counterpart in the Construction Directorate. Coordination is essential to maximize efficiency and productivity during the present period of intense activity during nighttime operations.

DAY AND EVENING TRACK MAINTENANCE ORGANIZATION

In addition to nighttime repair activities, day and evening crews work on visual inspection of track ("trackwalkers'), preventive maintenance (P.M.) and rubbish collection. The current, "Revised Track Repairmen's Schedule" is shown in Exhibit 3-4. Activities are divided using various job numbers to distinguish the territorial coverage for each assigned shift period (job). In each job category, the handwritten digit in the box indicates the number of personnel assigned to each job. When interpreting this schedule, the reader is asked to view the recommended frequency of trackwalking and preventative maintenance skeptically. Specific elaboration of this item is contained in the section on Maintenance Policy. For purposes of this section, the intended function of each job is discussed.

Trackwalking

Track condition monitoring, assessment, and defect identification is in large part, the responsibility of the trackwalker. As the name implies, this person walks the right-of-way (RoW) in an assigned track segment to identify and, in many cases correct, a track defect as delineated. Defects may be caused by weather-related track deterioration, train-induced wear, or acts of vandalism. In short, the task of a trackwalker is to administer both preventative and crisis-response maintenance. A problem area may be rectified on-site depending on its severity, replacement material requirements, and complexity. Further, some jobs must be done at night to avoid the imposition of line closure or speed restrictions in an affected area.

The trackwalker carries a large double-ended wrench, an all-purpose

Exhibit 3-4

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
REVISED TRACK REPAIRMEN'S SCHEDULE

	Sat.	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.
JOB #1 2							
Harvard to Charles North & Southbound	0	0	8-4:30N	8-4:30S	8-4:30	8-4:30N	8-4:30S
JOB #2 2							
Andrew Portal to South End Quincy Ctr. Platform	0	0	8-4:30N		8-4:30S		
South End Quincy Ctr. Platform to South End Braintree Sta. Platform				8-4:30NS		8-4:30NS	8-4:30NS
JOB #3 2							
Harvard Sta. to Andrew Portal	3:30-12MN	3:30-12MS	0	0			
Davis to Harvard					8-4:30NS		
Andrew Portal to South End Quincy Ctr. Platform						8-4:30N	8-4:30S
JOB #4 2							
Andrew to Charles North & Southbound Mattapan	0	0	8-4:30	8-4:30	8-4:30	8-4:30	8-4:30PM
JOB #5 2							
Andrew Portal to Trainmen's Platform Ashmont	0	0	8-4:30				8-4:30PM
Mattapan Line				8-4:30NS			
Codman Yard					8-4:30		
Cabot Yard						8-4:30	
JOB #6 2							
Forest Hills Sta. to Comm. Coll. Portal	0	0	8-4:30	8-4:30	8-4:30	8-4:30S	8-4:30N
JOB #7 2							
Forest Hills Sta. to Comm. Coll. Portal	8-4:30N	8-4:30S				0	0
Orange Line Preventive Maintenance			8-4:30	8-4:30	8-4:30		
JOB #8 1							
Orange Line Preventive Maintenance							8-4:30
Comm. Coll. Portal to Oak Grove Dead End	0	0	8-4:30E	8-4:30W	8-4:30E	8-4:30W	8-4:30E
JOB #9 1							
Forest Hills Yard	0	0	8-4:30		8-4:30		8-4:30
Wellington Yard				8-4:30		8-4:30	
JOB #10 2							
Bowdoin Yard to Wonderland Dead End	0	0	8-4:30E	8-4:30W	8-4:30E	8-4:30W	8-4:30E
JOB #11 2							
Bowdoin Yd. to Wonderland Dead End							
Blue Line Cover							
JOB #12 2							
Blue Line Preventive Maintenance							
JOB #13 2							
Four Portals to Copley Sta. (East End)	0	0	8-4:30EW	8-4:30EW	8-4:30EW	8-4:30EW	8-4:30EW
JOB #14 2							
Copley Sta. (East End) to Canal St. and Lechmere Yard	0	0	8-4:30EW	8-4:30EW	8-4:30EW	8-4:30EW	8-4:30EW
JOB #15 1							
Fenway Portal to Chestnut Hill (West End) including Reservoir Upper Yd.	0	0	8-4:30W			8-4:30W	
Chestnut Hill (West End) to Riverside				8-4:30E			
Riverside Yard					8-4:30		8-4:30E
JOB #16 1							
Riverside to Chestnut Hill (West End)	0	0	8-4:30E			8-4:30E	
Chestnut Hill (West End) to Fenway Portal				[illegible]			[illegible]
JOB #17 2							
Green Line Preventive Maintenance	0	0	8-4:30	8-4:30	8-4:30	8-4:30	8-4:30
JOB #18 2							
System Cover	8-4:30	8-4:30					
Green Line Cover				0	0	8-4:30	8-4:30
Riverside Yard			8-4:30				
JOB #19 2							
~~System Preventive Maintenance~~ Andrew to Charles North & Southbound	0	0	3:30-12M	3:30P-12M	3:30-12M	3:30P-12M	9:30-12M
JOB #20 2							
System Preventive Maintenance	3:30-12M	3:30-12M	3:30-12M	3:30-12M	3:30-12M	0	0
JOB #21 2							
Four Portals to Copley Sta. (East End)	3:30-12 EW	3:30-12EW					
Davis to Harvard			3:30-12M				
System Cover				0	0	3:30-12M	3:30-12M
JOB #22 2							
Copley Sta. (East End) to Canal St. & Lechmere Yard	8-4:30 EW	8-4:30 EW					
System Cover			8-4:30	8-4:30	0	0	8-4:30
JOB #23 4							
Night Trackwalkers	12M-7	12M-7	12M-7	12M-7	12M-7	0	0

Source: MBTA E & M Department

utility tool capable of turning bolts, prying and lifting components, hammering spikes, or moving tie plates. He or she may carry a distance measuring rule, but more commonly relies on tried and true experience to evaluate rail dips, cross-level, and gauge problem areas. Some trackwalkers carry a crayon in a pocket to mark problem areas for the road crew response.

An experienced trackwalker relies on judgement to determine the extent and severity of a problem; in general, and in lieu of more objective measures for classification and reporting purposes, a defect refers to any problem which requires either immediate or remedial maintenance action. Defect reports are often submitted by trackwalkers who identify problems, and report such to the section Foreman at the shift's end.

If the problem poses a potential safety risk to passing trains, the trackwalker may call the maintenance control center directly or alert the section foreman, mid-shift. In some cases, the trackwalker may be asked to stay on-site and act as a flagman to notify passing trains to slow down while crossing a broken rail, for instance. In this case, an emergency road crew would have been dispatched to the scene by the maintenance control center day man. Once dispatched, the trackman waits for the repair crew and his or her section foreman to arrive before continuing the walking inspection.

The trackwalker is reliable and trained to generate defect information, before a problem becomes a safety hazard. Many defects are corrected immediately, maximizing ride quality and increasing safety. A trackwalker inspects only a single direction of track during a given shift, whereas, in the past a trackwalker was responsible for both track directions in the same shift.

Track related defects are also reported by an assortment of sources, including Transportation and Operations Department personnel, police, and the general public. The reader should take note, however, that these sources are not specifically trained to isolate and identify track problems. Consequently, the reliability of reports generated by these sources may be questionable.

According to the track repairmen's schedule, no track segment is scheduled to be walked less than twice per week. Also according to the schedule, all subways are scheduled for daily trackwalker inspection coverage where, presumably the tracks are busiest and receive the most vehicle-induced deterioration.

Four night trackwalkers work between 12:00 A.M. and 7:00 A.M. Their coverage extends systemwide. Their individual locations are assigned based on anticipated need in a particular area. The task of a night trackwalker is identical to that of a day person. Of course, a night walker carries a flashlight to condust his or her activities.

A trackwalker will typically carry a bag of bolts and washers to repair broken or missing bolts (Code 10). Other on-site, repairable defects include gaps or "pull aparts" (Code 07) if not too severe, some insulation joint failures (Code 03) due to slivers or debris, minor switch point alignment problems (Code 11), rail loose or moving (Code 21). If the symptom is caused by a broken or missing anchor (Code 23) or loose spikes (Code 23). The trackwalker can remove tie plates which have moved (Code 26) from the joint area but generally cannot replace them with new ones. Tie plate replacement follows removal, or lifting of the rail, if the plate is double shouldered.

Defect categories which were not mentioned in the last category for immediate repair by the trackwalker are relayed to the Section Foreman and maintenance control center for subsequent disposition by the emergency road crew or night gangs.

Under the present system, trackwalkers meet at Cabot Yard for the Red Line, Maverick Station on the Blue Line, Dudley Station on the Orange Line and Haymarket on the Green Line. They turn in daily logs at these locations at the end of each shift to their respective line supervisor.

Preventative Maintenance

As can be seen from the repairmen's schedule, various crews are assigned to perform preventative maintenance (P.M.) system-wide and on a line by line basis. Line P.M. crews are assigned to Orange, Blue, and Green Lines. None are specifically assigned the Red Line P.M. function. The number of men assigned to each line is made according to management's perception of track condition, with the P.M. personnel assigned to the worst track conditions.

Theoretically, the name given to the P.M. crew is inaccurate. It implies that these men are engaged in activities which reduce the probability of a track defect incident before it happens. This would imply tightening bolts before they become loose, replacing worn rail, cleaning and replacing end posts, and assorted other preventative activities. This is not the practice. Instead, P.M. crews are typically engaged in trackwalking, rubbish collection along the tow, and light defect repair.

Emergency Road Crew

By day, the previously described joint crew, operates from 6:00 A.M. to 2:00 P.M. to service any rail-related track problem. Once again, the emergency road crew consists of a rail-capable truck driven by an operator from Local 589. On weekends, section foreman drives the truck. The emergency road crew is nicknamed the "200" crew and is a fairly recent development since the management rights bill in October, 1981. About five months prior to this writing, the crew truck operated only one eight hour shift per day, while it currently operates the day and night shift currently.

The on-board laborer, burner, grinder, or foreman, is capable of replacing fractured or broken rail (Code 09), installing/replacing temporary joing bars (Codes 06 and 07), installing a C-Bond or other type of bond (Code 04) or replacing worn or chipped rail (Codes 15,16, 17). The road crew may also fix switch alignments or rod problems (Codes 11 - 13), or defer to the Power and Signal division for spot maintenance at night.

MBTA BUDGET PROCESS

Each fiscal year, which commences July 1, a new operating budget is adopted to provide fiscal resources to all operating and non-operating departments. Emphasis will be placed on the operating departments only for the purposes of this study.

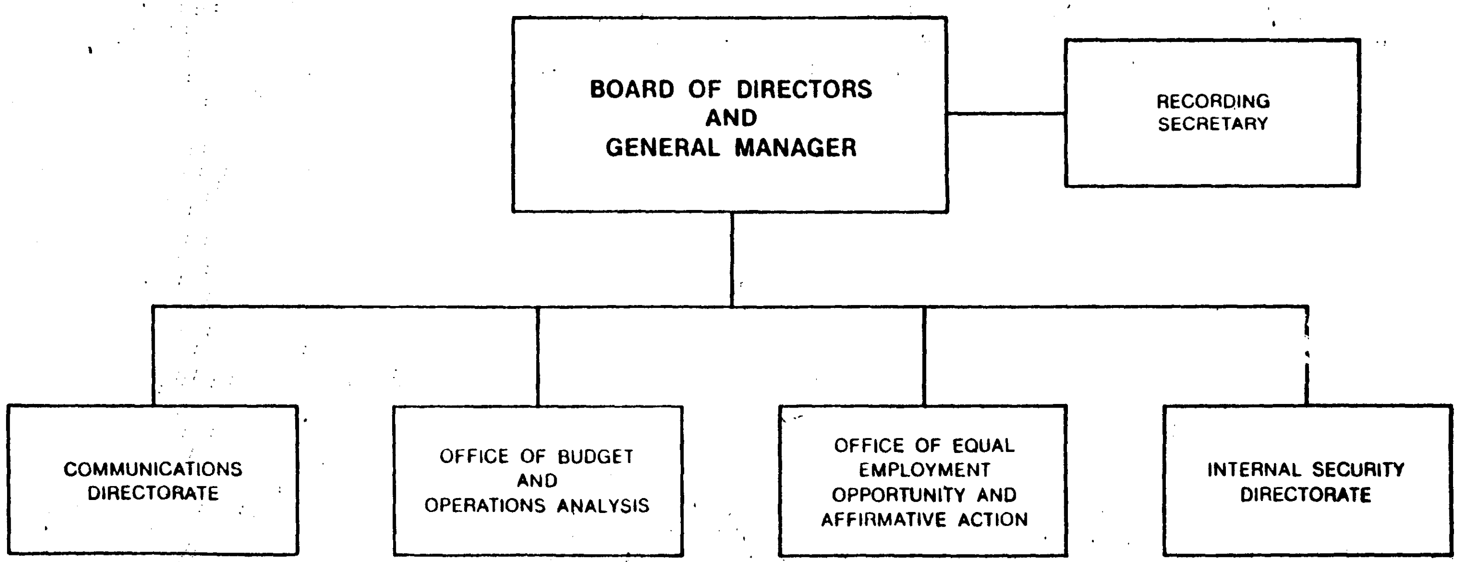
Exhibit 3-5 shows the organizational structure of the Executive Office--the Directorate which contains the Office of Budget and Operations Analysis. All operating departments interact with this Budget office to develop the scope and magnitude of fiscal year resource allocations by functional element. To best understand the way the budget works, the author will first present an excerpt from the FY 1983/1984 budget. The following description provides the reader with a formal charter of the budget mission:

> The Office of Budget and Operations Analysis reviews, prepares, and monitors the Authority's operating budget. As the Authority's key management aid, the budget process ensures that programs are cost effective, that they are affordable, and that they correspond to priorities set by the General Manager. This office also assists the General Manager and Departments in setting formal standards, goals, and objectives for management and service performance. The Office provides assistance to departments concerning planning, management, and organizational problems, helps them establish performance, measures and management reporting systems, and ensures that existing control systems are used to full advantage. Finally, the Budget Office conducts special anaylsis of operations and service costs.

In effect, the budget office acts as a liaison between all parties involved in the fiscal allocation of resources. Including the General Manager, Gerald O'Leary, and the MBTA Advisory board (documentation, negotiation, testimony, and presentations).

Exhibit 3-5

EXECUTIVE OFFICE



Source: 1983/1984 Operating Budget

Income is generated for the operating budget through a combination of three sources;

1) Revenue from the farebox, sale of commuter rail tickets, parking income, and other operations derived sources.
2) Income from a variety of investment instruments which pay interest, dividends,. or credits.
3) State funds consisting of property tax revenue disbursements and special funds which may be allocated from the Commonwealth's General budget.
4) Special funds

Income for maintenance and construction of track is administered by the Operating and Construction Directorates. Construction builds new track lines or extensions old lines. It acts as program manager for all new contractor performed track renewal programs (see Five-Year Plan). In general, the Construction Directorate less dependent on operating budget funds than the E & M Department, since its projects are eighty percent UMTA funded and twenty percent local (through MBTA recourses). Alternatively stated, the Construction Directorate deals directly with the Federal government for most of its program funds.

By inference, one could draw the logical conclusion that the Construction Directorate has more leverage with budget, the General Manager and Advisory board because all parties are intimately aware that the UMTA formula grant package requires a matching local portion. To kill the local match is to kill the program, from the perspective of the MBTA budget. Further, administrators get a four to one return on their initial investment ratio by providing a matching grant.

In contrast, Engineering and Maintenance Department track program requests provide only a one-to-one return portion from UMTA for operating and maintenance (O & M) funds. Since less federal support is leveraged in awarding resources to track maintenance programs, cuts in the O & M budget are more palatable than cuts in the construction budget.

Further, the maintenance function is inherently less visible than new construction activities of track programs. The author simply wishes to suggest that new-construction-in-transit is politically more appealing than keeping that which-is-in-operation running. Whatever reasons are ascribed to this scenario, recent evidence from past MBTA budgets supports the hypothesis.

Operating departments including Transportation and Construction were awarded exactly what was requested from the Advisory Board. Engineering and Maintenance consistently has one of the largest spreads between the amount proposed and the amount awarded. To demonstrate the need for and performance of immediate selective track maintenance, the E & M Department prepared a Red pictorial report for the Advisory board, "Special Track Work Program 1985-1985, 6 month interim report and FY 1986 requirements." An objective reviewer of the historical and present E & M department FY budgets might, also attempt to determine whether the budget request is realistic, given its program elements--in terms of the amount asked for in the original proposal. Without a zero-based budget approval, it is difficult to determine whether E & M Department budget requests include a buffer amount in anticipation of Advisory Board cuts. Perhaps only the players know for sure which scenario or combination of scenarios, are at work in this context.

The E & M Department budget-making process is similar to that of all operating departments, with the exception of unique special program funds which will be discussed in subsequent paragraphs.

Each fiscal year (FY), the budget building process is initiated with a letter sent from the Budget Office for next years' individual operating department request. Recently, all departments were put on "line" with a Klauder Associates designed MIS system designed to facilitate budget creation and other tasks. The letter asks each Operating Department to develop its next year's request element by element, e.g. Blue Line track tamping program, dividing costs into wages, materials, fringes, and services.

The next stop involves each operating department, in this case E & M, to cost all elements by expenditure category and submit the package to Budget. At this point, staff authorized members of the Budget staff will question the individual who submitted the request concerning a micro-level critique of proposed costs within each element. At this level, an assessment can be made whether the functional element will cost the same (base level), less, or more than last year's FY actual expenditure for the appropriate element. If the element is "above base-level", the E & M will be asked to justify the additional amount of funds requested.

Once this task is accomplished, budget representatives discuss the proposed E & M budget with the General Manager. He generates a series of questions in response to the presentation and may ask for further program justification from the department.

Next, the General Manager together with the Budget Department formulate a base budget to present to the Advisory Board after making a series of additions and deletions to the original departmental budget request.

By State statute, the Advisory Board has a forty-five to ninety-day period to respond to the General Manager's budget proposal during Advisory Board deliberations, the percentage of money allocated for preventative maintenance (P.M.) programs is scrutinized compared with that amount allocated for spot maintenance programs. The objective is to divert increasing amounts of expenditure for programmed maintenance. When the Advisory Board finishes, the approved budget is re-submitted to the Budget Office through James O'Leary, General Manager.

Before each Operating department is individually awarded its share of the approved budget, a final series of meetings is held with, for example, the E & M department. During this time, budget personnel ask the department what it will do with the money from a particular element if more resources were allocated than what is actually used. Similarly, the department must estimate the remaining resources in each functional category, based on the monthly rate of past expenditure and the number of funding months remaining in any specified program.

Finally the E & M Department receives its approved operating budget but the program monitoring activities of the budget process continue throughout the fiscal year until the new appropriation process begins.

This year, E & M was held approximately to last year's base level funds, or ten million dollars from the operating budget. In addition to the MBTA funded portion, the E & M department will receive about ten million dollars in UMTA formula section grants.

In addition to these income sources indicated previously, specific references will be made to revenue generated from alternative funding sources. These include revenue generated from the nickel gas tax and dispersed by the state for transit improvements known as Section 9A money. Funds from the gas tax were used this fiscal year to replace inoperable sump pumps and prolong track life.

The present two million dollar special track program for FY 1984/1985 was funded through an unanticipated surplus in the MBTA budget resulting from a favorable difference between estimated fixed charges outlays (interest payments on bonds-representing old and new debt) and that which was actually spent (due to a drop in interest rates). The total MBTA operating surplus was five million nominal dollars in FY 1983/1984. It was divided amongst the best competing proposals for various special programs in selected operating departments; E & M got forty percent of total funds on a one-time only basis. Revenue sources for the FY 1985/1986 special track program are currently being investigated and are uncertain at the time of this writing.

A special program was created to maintain and slightly upgrade the Orange Line elevated structure. Under Chapter 480, of the Massachusetts General Laws, a special one million dollar earmarked fund was created to fund the Orange Line structure maintenance program until it is dismantled, to be replaced by the scheduled 1986 opening of the Southwest Corridor project.

A possible, but as yet uncommitted source of revenue for station improvements and remodeling may come from another discretionary state fund, Chapter 745 for beautification of public facilities in the Commonwealth. This money would come from the State budget surplus.

By now it should become obvious that a great deal of E & M department funds are allocated on a short-term basis with descretionary funds. The degree and amount which these funds are allocated to E & M is a function of the quality and need of competing proposals, as well as the tenacity and diplomacy demonstrated by E & M staff in proposal submission and negotiation. A major factor in awarding Special Program appropriations is need and saftey inherent in the project. In the case of the Orange Line structure, catwalks were unsafe for maintenance staff and rail guard rails and cross ties were viewed as deficient for safe operations.

Special Track Repair Program

The Special Track Program began on July 1, 1984 and is currently funded through June 30, 1985. As indicated in the section concerning the Budget Process, two million dollars was received from a one-time fixed charges surplus derived from the previous Budget. Funding for this Program will be exhausted unless a new source of income is found. Of the sixty two laborers who were hired for this activity, fifty six will be retained on the permanent payroll.

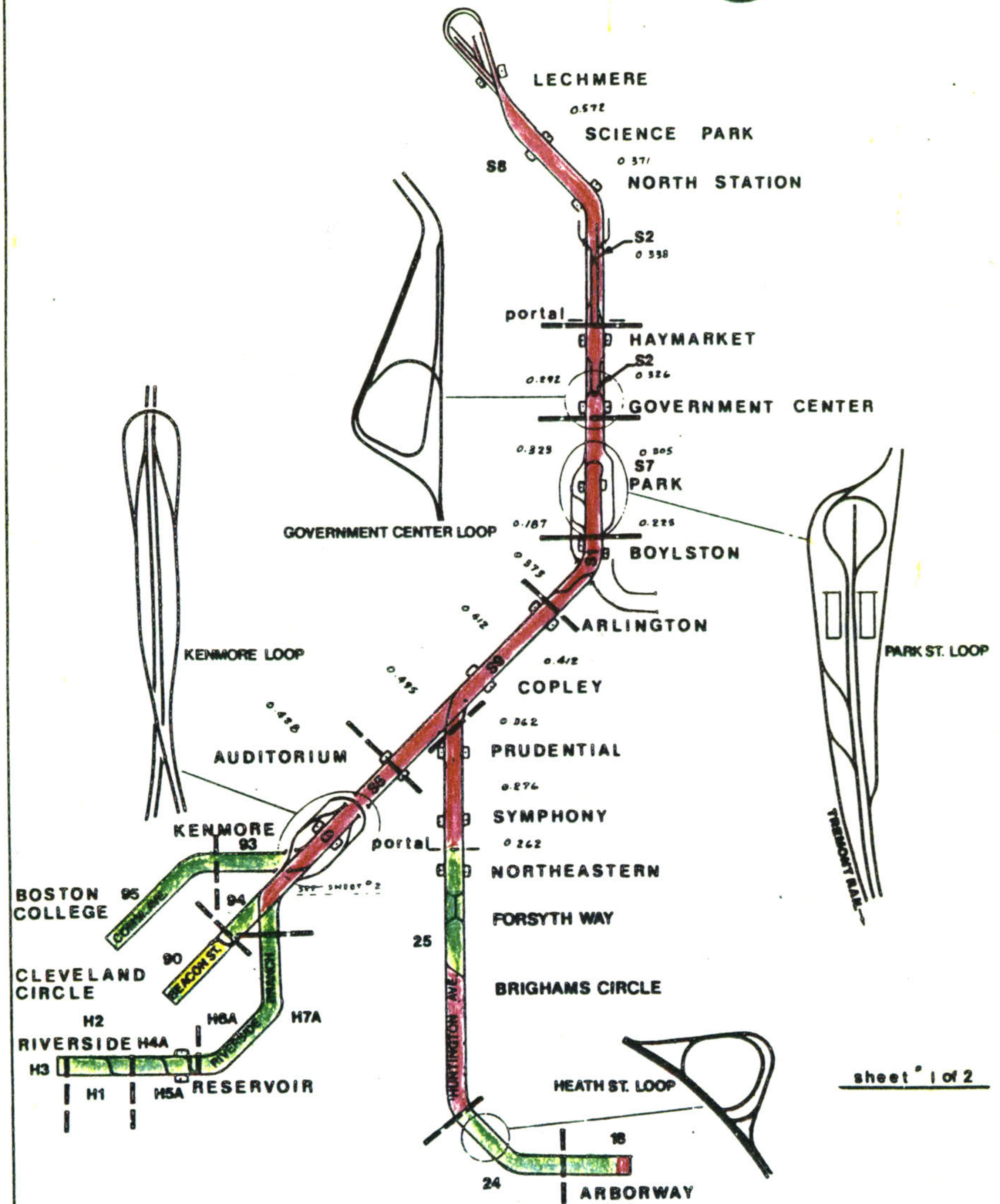
The Program is primarily a series of selective maintenance actions designed to enhance track quality in locations where deferred maintenance is greatest. Two track schematics are excerpted directly from the MBTA Interim Progress Report and presented in Exhibit 4-1 and Exhibit 4-2, respectively. The schematic denotes track condition status on the first day of the Program, July 1,]984 and after six months of continuous activity. Red is used to denote poorest track quality, yellow for moderate quality and green for best quality. The map is based on "Detailed walking inspections of our system" (Special MBTA Trackwork Program 6 Month Report, December, 1984). It should be pointed out that detailed walking inspections are highly subjective measures which may be introduce inconsistent bias due to lack of uniformity amongst the opinion of track inspectors.

An alternative method of determining track condition is to develop a track quality index (Markow, 1982, Bing, 1983, FRA, 1980) to prioritize track repair scheduling by location. Because the proposed index relies on track geometry measures for which the "T" cannot assess until it relieves its on-order track geometry car, the author suggests using some of the performance measures discussed in the concluding chapter to allocate maintenance levels by location and amount. More simply,

TRACK CONDITIONS PRIOR TO JULY 1, 1984

Table 4-1

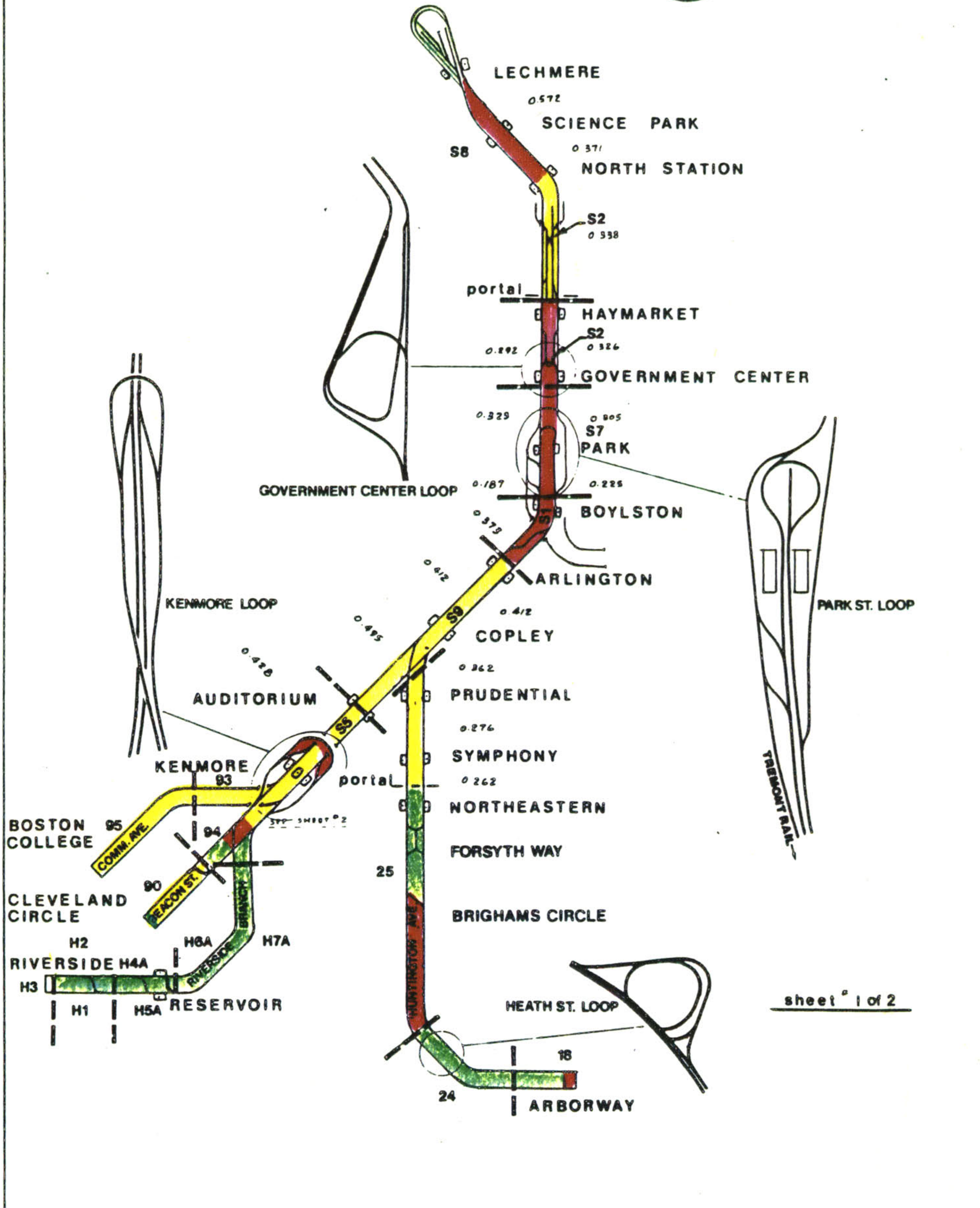
GREEN LINE
TRACK SCHEMATIC



TRACK CONDITIONS DECEMBER 28, 1984

GREEN LINE TRACK SCHEMATIC

Table 4-2



5-7-80 GJC
REV. 5-11-84 DWH

resources should be allocated based on the highest incidence of track-related defects per unit-mile of track.

The assertion that the Special Track program is really merely a spot repair program is valid, with one major exception. Based on a line-by-line review of maintenance activity, it appears that a good part of Green Line repairs can be considered track renewal since substrate, ballast, ties, fasteners and running rail were replaced at nearly 100% levels in designated areas.

Although it is premature at this time and the Special Track program is currently invaluable in the short term, a slow transition to programmed maintenance in future years is desirable to avert the need for deferred maintenance corrective actions in the future.

With the creation of the Special Track program came a computerized MIS developed for, and capable of, program expenditure monitoring by work element. Three types of reports can be generated for productivity monitoring, materials expenditure, and labor expenditure. Monthly

program reports, produced at the station level, could be utilized to assess the percentage of spot-repairs made by program activity code (Tabel 4-4). The design of this MIS was clearly developed to serve the stated budget office objectives to development performance measures and program control. For analytic purposes, however, the reporting system is extremely crude. It is impossible to determine the exact location where work, such as running rail replacement (Code 01) was done and what exactly was done. For instance, it is simply not possible to replace running rail without first removing the old fasteners and anchors, cutting the old rail, if it is welded, often reballasting or tamping, and welding the new rail in place.

See Tables 4-1 through 4-3 for examples of the Special Track Program Productivity Report, Materials Expenditure Report, and Labor Expenditure Report.

Table 4-1

M.B.T.A. SPECIAL FY85 TRACK REPAIR PROGRAM   PRODUCTIVITY REPORT   7/1/84 - 12/28/84 (50.00% OF FY85)   GREEN LINE

WORK ELEMENT	UNIT	ESTMTD TOTAL QUANTITY	ESTMTD TOTAL MANHOURS	ESTMTD MIN/ UNIT	ACTUAL QUANTITY	ACTUAL HOURS EXPENDED	ACTUAL MIN/ UNIT	% UNITS COMPLTD	% LABOR HOURS EXPEND.	PRODUC-TIVITY INDEX
RUNNING RAIL INSTALLATION	FEET	16,640	6,160	22	8,742.0	2,840.0	19	52.5%	46.1%	114.0
RAIL FITTING & ADJUSTING	FEET	8,000	800	6	4,144.0	511.0	7	51.8%	63.9%	81.1
SPECIAL TRACKWORK INSTALL	EACH	15	795	3,180	5.0	278.0	3,336	33.3%	35.0%	95.3
TRACK REGAUGING	FEET	20,000	5,000	15	5,522.0	853.0	9	27.6%	17.1%	161.8
RAIL JOINT BAR RENEWAL	EACH	550	1,100	120	324.0	321.0	59	58.9%	29.2%	201.9
INSULTN JOINT BAR RENEWAL	EACH	73	584	480	45.0	234.0	312	61.6%	40.1%	153.8
RAIL ANCHORING	FEET	7,500	750	6	2,462.0	322.0	8	32.8%	42.9%	76.5
RESTRAINING RAIL INSTALL	FEET	2,200	550	15	20.0	60.0	180	0.9%	10.9%	8.3
RAIL BRACE INSTALLATION	EACH	343	2,401	420	121.0	663.0	329	35.3%	27.6%	127.8
BACK SHIM/FLNGWAY REGAUGE	FEET	12,480	3,744	18	2,220.0	560.0	15	17.8%	15.0%	118.9
THIRD RAIL INSTALLATION	FEET									
THIRD RAIL REGAUGING	FEET									
INSULATOR RENEWAL	EACH									
CROSS TIE INSTALLATION	EACH	1,500	9,000	360	979.0	7,348.0	450	65.3%	81.6%	79.9
SWITCH TIE INSTALLATION	EACH	260	3,120	720	10.0	232.0	1,392	3.8%	7.4%	51.7
STRUC/TANGENT TIE INSTALL	EACH	200	1,400	420	0.0	0.0	#DIV/0	0.0%	0.0%	#DIV/0!
STRUC/CURVE TIE INSTALL	EACH									
TIE PLATE REPLACEMENT	EACH	2,000	2,000	60	647.0	593.0	55	32.4%	29.7%	109.1
PRODUCTION TAMPING	FEET									
SPOT TAMPING	FEET	13,800	2,830	12	12,076.0	1,879.0	9	87.5%	66.4%	131.8
SWITCH TAMPING	EACH	17	1,550	5,471	1.0	48.0	2,880	5.9%	3.1%	190.0
WELDING/SPECIAL TRACKWORK	EACH	23	805	2,100	45.0	1,107.0	1,476	195.7%	137.5%	142.3
WELDING/SIGNAL BONDS	EACH	1,315	2,860	130	246.0	386.0	94	18.7%	13.5%	138.6
WELDING/THERMITE (CWR)	EACH	34	680	1,200	0.0	0.0	#DIV/0	0.0%	0.0%	#DIV/0!
MATERIAL HANDLING - TIES	EACH	2,620	1,917	44	1,648.0	1,423.0	52	62.9%	74.2%	84.7
MATERIAL HANDLING - RAIL	FEET	16,840	1,347	5	18,283.0	1,374.0	5	108.6%	102.0%	106.4
RUBBISH CLEAN-UP	HOUR	2,600	2,600	60	1,347.0	1,347.0	60	51.8%	51.8%	100.0
TRAINING/LABORERS	EACH	23	3,680	9,600	22.2	3,549.0	9,592	96.5%	96.4%	100.1
TRAIN/WELDERS & GRINDERS	EACH	3	480	9,600	0.4	64.0	9,600	13.3%	13.3%	100.0
TRAINING/FOREMEN	EACH	3	480	9,600	1.6	256.0	9,600	53.3%	53.3%	100.0
TOOLS & EQUIPMENT										
			56,633	31		26,248.0	27	46.7%	46.3%	100.8

Source: MBTA, 1985

Table 4-2

M.B.T.A. SPECIAL FY85 TRACK REPAIR PROGRAM   MATERIALS EXPENDITURES REPORT   7/1/84 - 12/28/84 (50.00% OF FY85)   GREEN LINE

WORK ELEMENT	UNIT	ESTIMATED TOTAL QUANTITY	ESTIMATED MATERIALS COST/UNIT	ESTIMATED MATERIALS TOTAL COST	ACTUAL QUANTITY	ACTUAL MATERIALS COST	% UNITS COMPLETED	% MTRL. $ EXPEND.
RUNNING RAIL INSTALLATION	FEET	16,640	$9.22	$153,434	8,742.0	$80,608	52.5%	52.5%
RAIL FITTING & ADJUSTING	FEET	8,000			4,144.0		51.8%	
SPECIAL TRACKWORK INSTALL	EACH	15	$2,305.20	$34,578	5.0	$11,526	33.3%	33.3%
TRACK REGAUGING	FEET	20,000			5,522.0		27.6%	
RAIL JOINT BAR RENEWAL	EACH	550	$57.63	$31,697	324.0	$18,672	58.9%	58.9%
INSULTE JOINT BAR RENEWAL	EACH	73	$253.57	$18,511	45.0	$11,411	61.6%	61.6%
RAIL ANCHORING	FEET	7,500	$1.15	$8,645	2,462.0	$2,838	32.8%	32.8%
RESTRAINING RAIL INSTALL	FEET	2,200	$9.22	$20,286	20.0	$184	0.9%	0.9%
RAIL BRACE INSTALLATION	EACH	343	$115.26	$39,534	121.0	$13,946	35.3%	35.3%
BACK SHIM/FLNGWAY REGAUGE	FEET	12,480	$1.73	$21,577	2,220.0	$3,838	17.8%	17.8%
THIRD RAIL INSTALLATION	FEET							
THIRD RAIL REGAUGING	FEET							
INSULATOR RENEWAL	EACH							
CROSS TIE INSTALLATION	EACH	1,500	$18.28	$27,422	979.0	$17,898	65.3%	65.3%
SWITCH TIE INSTALLATION	EACH	260	$25.36	$6,593	10.0	$254	3.8%	3.8%
STRUC/TANGENT TIE INSTALL	EACH	200	$38.04	$72,600	0.0	$0	0.0%	0.0%
STRUC/CURVE TIE INSTALL	EACH							
TIE PLATE REPLACEMENT	EACH	2,000	$6.92	$13,831	647.0	$4,474	32.4%	32.4%
PRODUCTION TAMPING	FEET							
SPOT TAMPING	FEET	13,800			12,076.0		87.5%	
SWITCH TAMPING	EACH	17			1.0		5.9%	
WELDING/SPECIAL TRACKWORK	EACH	23	$86.45	$1,988	45.0	$3,890	195.7%	195.7%
WELDING/SIGNAL BONDS	EACH	1,315	$7.49	$9,852	246.0	$1,843	18.7%	18.7%
WELDING/THERMITE (CWR)	EACH	34	$86.45	$2,939	0.0	$0	0.0%	0.0%
MATERIAL HANDLING - TIES	EACH	2,620			1,648.0		62.9%	
MATERIAL HANDLING - RAIL	FEET	16,840			18,283.0		108.6%	
RUBBISH CLEAN-UP	HOUR	2,600			1,347.0		51.8%	
TRAINING/LABORERS	EACH	23			22.2		96.5%	
TRAIN/WELDERS & GRINDERS	EACH	3			0.4		13.3%	
TRAINING/FOREMEN	EACH	3			1.6		53.3%	
TOOLS & EQUIPMENT				$75,000				
				$538,486		$171,383		31.8%

Source: MBTA, 1985

Table 4-3

M.B.T.A. SPECIAL FY85 TRACK REPAIR PROGRAM — LABOR EXPENDITURES REPORT — 7/1/84 - 12/28/84 (50.00% OF FY85) — GREEN LINE

WORK ELEMENT	UNIT	ESTMTD MIN/ UNIT	LABOR COST/ HOUR	ESTIMATED LABOR COST/UNIT	ESTIMATED LABOR TOTAL COST	ACTUAL MIN/ UNIT	ACTUAL LABOR COST/UNIT	ACTUAL LABOR COST	% LABOR $ EXPEND.	% LABOR COST/UNIT VARIANCE
RUNNING RAIL INSTALLAT	FEET	22	$16.61	$6.15	$102,318	19	$5.40	$47,172	46.1%	-12.2%
RAIL FITTING & ADJUSTI	FEET	6	$16.61	$1.66	$13,288	7	$2.05	$8,488	63.9%	23.3%
SPECIAL TRACKWORK INST	EACH	3,180	$16.61	$880.33	$13,205	3,336	$923.52	$4,618	35.0%	4.9%
TRACK REGAUGING	FEET	15	$16.61	$4.15	$83,050	9	$2.57	$14,168	17.1%	-38.2%
RAIL JOINT BAR RENEWAL	EACH	120	$16.61	$33.22	$18,271	59	$16.46	$5,332	29.2%	-50.5%
INSULTN JOINT BAR RENE	EACH	480	$16.61	$132.88	$9,700	312	$86.37	$3,887	40.1%	-35.0%
RAIL ANCHORING	FEET	6	$16.61	$1.66	$12,458	8	$2.17	$5,348	42.9%	30.8%
RESTRAINING RAIL INSTA	FEET	15	$16.61	$4.15	$9,136	180	$49.83	$0	0.0%	1,100.0%
RAIL BRACE INSTALLATIO	EACH	420	$16.61	$116.27	$39,881	329	$91.01	$11,012	27.6%	-21.7%
BACK SHIM/FLNGWAY REGA	FEET	18	$16.61	$4.98	$62,188	15	$4.19	$9,302	15.0%	-15.9%
THIRD RAIL INSTALLATIO	FEET									
THIRD RAIL REGAUGING	FEET									
INSULATOR RENEWAL	EACH									
CROSS TIE INSTALLATION	EACH	360	$16.61	$99.66	$149,490	450	$124.67	$122,050	81.6%	25.1%
SWITCH TIE INSTALLATIO	EACH	720	$16.61	$199.32	$51,823	1,392	$385.35	$3,854	7.4%	93.3%
STRUC/TANGENT TIE INST	EACH	420	$16.61	$116.27	$23,254	#DIV/0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
STRUC/CURVE TIE INSTAL	EACH									
TIE PLATE REPLACEMENT	EACH	60	$16.61	$16.61	$33,220	55	$15.22	$9,850	29.6%	-8.3%
PRODUCTION TAMPING	FEET									
SPOT TAMPING	FEET	12	$16.61	$3.41	$47,006	9	$2.58	$31,210	66.4%	-24.1%
SWITCH TAMPING	EACH	5,471	$16.61	$1,514.44	$25,746	2,880	$797.28	$797	3.1%	-47.4%
WELDING/SPECL TRKWORK	EACH	2,100	$16.61	$581.35	$13,371	1,476	$408.61	$18,387	137.5%	-29.7%
WELDING/SIGNAL BONDS	EACH	130	$16.61	$36.13	$47,505	94	$26.06	$6,411	13.5%	-27.9%
WELDING/THERMITE (CWR)	EACH	1,200	$16.61	$332.20	$11,295	#DIV/0	#DIV/0!	$0	0.0%	#DIV/0!
MATERIAL HANDLING-TIES	EACH	44	$16.61	$12.15	$31,841	52	$14.34	$23,636	74.2%	18.0%
MATERIAL HANDLING-RAIL	FEET	5	$16.61	$1.33	$22,374	5	$1.25	$22,822	102.0%	-6.0%
RUBBISH CLEAN-UP	HOUR	60	$16.61	$16.61	$43,186	60	$16.61	$22,374	51.8%	0.0%
TRAINING/LABORERS	EACH	9,600	$16.61	$2,657.60	$61,125	9,592	$2,655.36	$58,949	96.4%	-0.1%
TRAIN/WELDERS & GRINDE	EACH	9,600	$16.61	$2,657.60	$7,973	9,600	$2,657.60	$0	0.0%	0.0%
TRAINING/FOREMEN	EACH	9,600	$16.61	$2,657.60	$7,973	9,600	$2,657.60	$4,252	53.3%	0.0%
TOOLS & EQUIPMENT										
				$8.63	$940,674		$7.29	$429,667	45.7%	-15.5%

Source: MBTA, 1985

TABLE 4-4

SPECIAL TRACK PROGRAM ACTIVITY CODES

01	RUNNING RAIL INSTALLATION
02	RAIL FITTING & ADJUSTING
03	SPECIAL TRACKWORK INSTALLATION
04	TRACK REGAUGING
05	RAIL JOINT BAR RENEWAL
06	INSTALLATION-JOINT BAR RENEWAL
07	RAIL ANCHORING
08	RESTRAINING RAIL INSTALLATION
09	RAIL BRACE INSTALLATION
10	BACK SHIM/FLANGEWAY REGAUGING
11	THIRD RAIL INSTALLATION
12	THIRD RAIL REGAUGING
13	INSULATOR RENEWAL
14	CROSS TIE INSTALLATION
15	SWITCH TIE INSTALLATION
16	STRUCTURAL/TANGENT TIE INSTALLATION
17	STRUCTURAL/CURVE TIE INSTALLATION
18	TIE PLATE REPLACEMENT
19	PRODUCTION TAMPING
20	SPOT TAMPING
21	SWITCH TAMPING
22	WELDING/SPECIAL TRACKWORK
23	WELDING/SIGNAL BONDS
24	WELDING THERMITE - CONTINUOUS WELDED RAIL (CWR)
25	MATERIAL HANDLING - TIES
26	MATERIAL HANDLING - RAIL
27	GROUND & POWER WELDING

The Five-Year Plan

A five-year plan is prepared by the E & M Department to establish management goals and objectives. It is submitted directly by the Chief Engineer to the Director of Operations for approval. The most recent plan update available for review was prepared on May 26, 1983. The author believes the plan has been revised since 1983 but the latest revision was not available at the time of this writing.

With regard to track maintenance, the plan establishes several particularly pertinent objectives, in addition to stated labor productivity goals:

- Reconstruct or upgrade all track systems which have not been rebuilt during the past twenty years

- Comm. Ave. (segments A & C), Orange Line Structure, Huntington Ave. (Northeastern to Brigham's Circle)	1980
- Dorchester Rapid Transit Line, Mattapan High Speed Line, Orange Line Structure	1981
- Beacon Street, Lake Street Yard, Reservoir Yard	1982
- Blue Line, Mattapan Yard, Lechmere Yard, Comm. Ave., (Segment B), Reservoir Yard	1983
- Green Line Subway (Haymarket to Park), Riverside Riverside Yard	1984
- Green Line Subway (Park to Copley and Northeastern Portal), Arborway Yard, Arborway Line (Brigham's Circle to So. Huntington Ave.)	1985
- Green Line Subway (Copley to Blandford and St.Mary's), Codman Yard	1986
- Red Line (Andrew to Harvard), Orient Heights Yard	1987
- Blue Line Subway, Green Line (Lechmere to Haymarket)	1988
- Orange Line Subway	1989

- Design and implement a Management Information System integrating same with on-line equipment and data for materials, budget, and accounts payable which will provide us with sufficient historical data so as to enable us to analyze our maintenance functions, assist in developing standards, improve present maintenance estimating techniques, and determine the cost-effectiveness of our maintenance through defect reporting documentation. Establish an engineering data bank.

  - Design-Development-Maintenance Control Center Work Order System — 1982
  - System Installation, Test, and Shakedown — mid-1983
  - System On-Line — late 1983

  Author's Note: the revised system installation and shakedown has been rescheduled to November, 1985

- Implement Performance Monitoring Objectives Management Program

  - Trial Quarter and Shakedown — last quarter 1982
  - Monitor -- weekly, monthly, quarterly, and annually

- Analyze our present preventive maintenance program status against the key preventive maintenance management elements and implement a detailed and documented computer-based maintenance program which will reduce the number of defect reports by 20% over a 1980 base:

3 %	-	1981
6 %	-	1982
10 %	-	1983
15 %	-	1984
20 %	-	1985

  Author's Note: from this objective, it is not clear how defect reports are to be reduced; whether inspection frequency reductions will reduce the number of [cont.]

reported defects or whether the defects will not actually occur in future years.

- Reduce track-related speed restrictions in 1981 thru 1985.

- Reduce rail-related derailments by 40% compared to 1980 base

  10 % - 1981
  15 % - 1982
  25 % - 1983
  35 % - 1984
  40 % - 1985

SURVEY OF ANALYTICAL TECHNIQUES AND APPLICATIONS

The objective of this chapter is to provide a survey and evaluation of techniques used, or usable, for track maintenance resource allocation. Presently, Engineering and Maintenance Management are "issued" a budget which is allocated to support a variety of functional areas including automatic fare signals, collection equipment, building and structures, signals, and right-of-way. Although track is a major E & M Department responsibility area, it is not the only function competing for scarce resources. Certain funds, such as 80/20% matching UMTA track capital program resources are tied to specific projects. Hence, it may not be possible to completely control the allocation of the maintenance budget, based solely on a set of performance measures or the strength of a set of coefficients generated by a simulation model output.

Rather, the purpose of developing an analytical framework is to monitor track performance and allocate those track resources which are fully controlled by E & M Department personnel. The author emphasizes that the techniques presented herein should be viewed merely as decision aids, never intended to surpass the sound judgement and proven experience demonstrated by the E & M organization staff.

This chapter begins with a comparison of the railroad versus a transit operating environment. The next section presents a critique of the literature reviewed for this study. The literature is intended to provide a synopsis of techniques which have been utilized to study maintenance resource input allocation, model track performance relationships, and project track quality.

Comparison of Transit Versus Railroad Operating Environment

A great deal of research has focused on railroad truck maintenance models (Bing, 1983; Zobrak, 1980; Japan National Railways, 1967; Markow, 1982; Love, 1981). Comparatively little effort has been directed on transit track maintenance research (Smith, 1985). This section begins with the assumption that the two operating environments are analytically similar and addresses what can be learned from the railroad operating environment and how it is different from transit.

Performance of track maintenance on mainline railroads is not usually hindered by tight RoW clearances (height above rail head and side clearance) and sharp radii curves as those of transit operations. Consequently, it is possible to use long, fully automated, MoW trains to perform major track renewals quickly and relatively cheaply using a capital intensive approach. Maintenance operations on transit subway or elevated track is generally hostile to any stock MoW equipment designed for railroad use, unless extensively modified or custom built. The resulting labor-intensive approach to transit track renewal and maintenance is relatively antiquated.

The oldest transit property in the nation, has extremely tight clearance restrictions in tunnel operations, weight restrictions on the elevated structure, and a great deal of special trackwork which dictates manual maintenance methods. The MBTA is slowly entering the era of automated track technology with its recent contract to build a third rail capable and commuter rail track geometry car. In general, most of the high technology railroad MoW equipment such as mobile flashbutt welders for continous welded (CWR) rail fabrication in the field, is not yet in the planning stages at the "T".

Railroads generally move the bulk of their freight trains late at night and in the early morning hours, while transit peak periods occur 7:00 - 9:00 a.m. and 4:00 - 6:00 p.m. with a mid day mini-peak period during the lunch hour. Further, some transit properties (Chicago, New York, Philadelphia) operate 24 hours per day, never closing. Fortunately, heavy maintenance at the MBTA can be performed during non-revenue hours between midnight and seven a.m.

Because railroad mainline headways are so infrequent compared with, for instance, four minute peak headways on the Red Line, it is possible to schedule certain heavy repairs between trains, during daylight hours, at many railroads. If a line is closed for track renewal, commodities such as grain are less sensitive to additional trip time than passengers in subways. When combined, these factors hinder the efficiency associated with transit track maintenance labor and material productivity.

Railroad track is designed for heavier loads than transit track. Load factors are a much smaller contributor to gross vehicle weight in transit than railroad vehicles. For purposes of vehicle-induced track deterioration, the author suggests using the number of vehicle trips to evaluate rail head and side wear, rather than the railroad proxy, millions of gross tons (MGT) per year.

Maintenance allocation fortransit track also requires a recognition that station spacing is frequent, causing vehicles to accelerate and brake more frequently than on freight mainlines. Based on this, it can be inferred that rail head wear, rail joints and insulation joints are subject to accelerated wear in transit use.

Because transit track handles lighter weights, track construction standards are less rigorous than those of railroad track; using 85, 100, and 115 pound rail instead of 132 pound rail weight (weight measured per rail-yard.) Tie plates, spikes, and fasteners are also less substantial in transit track applications. At the MBTA, rail engineers are increasingly specifying heavier rail during change-outs because of its extended life and lower capital to labor ratio for capital improvement programs.

A further difference in the operating climate is the cyclical nature of rail track demand versus the relatively constant level of service provision in transit operations. For study purposes, this means that once a transit track preventive maintenance cycle is established, it can be implemented without regard to service changes. Further, the ability to allocate maintenance resources is enhanced by the steady state operating climate of transit. This is an important distinction when modeling maintenance demand.

Finally, the traditional return on investment (ROI) analysis used to prioritize track renewal activities used at certain railroads (see Folk, 1977) is not appropriate for use at the MBTA. The methodology must be modified to incorporate sensitivity analysis for state or federal project grants.

Critique and Application of the Literature Review

An introduction to the most general literature on transportation maintenance principals demonstrates that a great deal of work has been done in the areas of aviation maintenance, reliability, and engineering redundancy for--systems with components whose catastrophic failure would pose an imminent risk to personal safety. However, for purposes of brevity, much of the original motivation for developing analytical methods for maintenance performance evaluation comes from the field of military aviation.

A comprehensive review of track maintenance literature outlines at least three predominant schools of thought concerning approaches to track maintenance management. These are:

1) the mechanical and civil engineering approach
2) the financial approach
3) the economic approach

The author believes the optimal approach to track maintenance management incorporates elements from all three approaches and thus, analytical techniques serve as an input to sound track maintenance policy.

"Cookbook" Approaches to Track Maintenance

The Track Cyclopedia (AAR, 1978) is a compendium of information on track construction, design and maintenance. It is broadscope and begins with track contractor advertising, and it also includes a dictionary of track-specific terminology. Substantive chapters address engineering specifications and give "how-to" guides for right-of-way, stabilization and drainage, grading, ballast and associated equipment, surfacing and alignment, ties, rails, and joints and anchors. The text then proceeds to detail track maintenance and renewal techniques. The latter two subjects are perhaps the most interesting. They introduce tie and rail renewal cycles to satisfy minimum FRA standards by track class. However, the text falls short of correlating the maintenance supply function with that of demand, but, because the text's target audience is railroad staff, this may not be viewed as a deficiency by those readers.

The last section consists of a reprint of the FRA safety standards, and illustrative photographs abound throughout the text, making it well-documented and useful, especially for those unacquainted with the appearance of track MoW equipment.

Railroad Track Theory and Practice (Fastenrath, 1977) is a series of technical papers derived from and put into practice at the German Federal Railroad. It is an exhaustive text designed for individuals interested in learning the underlying train-to-track dynamics to better design and engineer track construction and maintenance. The principal utility of the text is its clear and thorough coverage of track mechanical engineering relationships and liberal use of simplified stress, rail wear, and axle load formulas. The book is marginally useful to a transit rail engineer involved in the procurement of rail and development of acceptance specifications for the manufacturer. It is strictly a series of sophisticated engineering case studies which are not supported by economic and costing relationships. Therefore, it can contribute little to this study,

The Rail Defect Manual (Sperry Rail, 1968) is a pamphlet-sized text which describes the milling process used to manufacture rail and describes all the possible rail flaws which may occur. Because the text is intended as a marketing brochure to encourage the use of Sperry Rail Flaw Detection Cars, the definitions of each rail defect type do not conform to the A.R.E.A. standards --a minor criticism, but it is nonetheless, thoroughly educational for the study of rail defect identification.

The last of what the author has categorized as "cookbook" texts is the proceedings of a 1978 OECD conference, "Maintenance Techniques for Road Surfacings". Although this research is primarily intended for road surface maintenance applications, many of the articles present basic concepts which are applicable to track maintenance. These are:

- Development of road [read: track] categories [classes]
- Deterioration, including traffic [vehicle-trips]
- Climate [weather-related deterorіation]
- Design [track construction quality]

The chapter concerning maintenance planning, scheduling and execution is most valuable. It presents methods of maintenance priority scheduling based on inspection cycles and developing road [track] quality [input mix] and quantity [input amounts] levels for maintenance supply. The research is conceptually innovative in its approach to an intensive maintenance policy and is cost-effective in the long run.

Track Degradation Modeling

A great majority of track maintenance is based on a series of observations, over time, of track conditions; i.e., deterioriation with continued use (usually measured in millions of gross tons per time interval) and age. Some of this work is reviewed here to provide the reader an evolutionary account.

A Japanese National Railways (1967) report establishes the method of maintenance employed on its railroads. In addition to a full treatise on tangent and curved rail specifications, MoW equipment, and mechanical modeling of track dynamics, the report furnishes a description of track condition monitoring programs.

The Japanese have been monitoring track geometry, rail deflection, and wear, since 1953 (JNR, p. 74, 1967) using a track inspection car. Cars check longitudinal level, gauge, alignment and cross-level of track

maintenance planning using the following simple model:

$$S = \frac{b - a}{m}$$

Whereas:

- S = Growth of track irregularity (MM/day)
- b = Track irregularity in MM. in the identical location, remaining for N days after adjustment
- a = Track irregularity (in mm.) immediately after adjustment
- m = number of days until the next adjustment

The report also presents a section "Maintenance Work of Track". In this section the track renewal cycle is considered by track class:

Class A repair

> Depending on the importance of the section, the whole track is reconditioned at a cyclic period of 2 to 4 years, primarily by replacing deteriorated materials and by overall tamping, the latter meaning tamping of ballast over whole
> [cont.]

stretches of track as specified. Each work section is divided into 2 or 4 sub-sections, of which one undergoes repair annually.

It can be concluded that track maintenance policy in Japan (in 1967) favored frequent spot maintenance for failed ties, anchors, and worn rail, as well as production tamping--an inherently preventive maintenance function if performed on a regular basis.

Takahara (JNR, 1979) provides a method for predicting track degradation for Amtrak's Northeast Corridor. Based on work conducted on Shinkansen Lines, a model to determine the frequency of surfacing is developed using various vehicle wear coefficients to cumulatively derive deterioration. These are presented for a track structure coefficient which uses ballast pressure, vibration, and rail impact. A "baseline" track is established to create an index to measure a particular track segment. Also considered in the track degradation model is a load coefficient for various equipment types and operating frequencies.

The models yield accurate results for forecasting maintenance resource allocations in the future but require a great deal of intensive data. It is not known whether this program is in use at Amtrak.

In 1978, the Federal Railroad Administration (FRA) launched a program to improve track safety and performance. A total of five final reports which were sponsored by that program are reviewed in this chapter; two of which are categorized as track degradation models, while three studies use life-cycle costing to address optimal scheduling of track renewal programs. The latter research efforts are reviewed in the economic analysis section.

A comprehensive empirical and engineering analysis of track degradation modeling on Conrail track was performed by Bing, (1983). This FRA-sponsored report reviews past relevant research, discusses the factors affecting track deterioration including traffic type and mix, maintenance, soil characteristics, and environmentally-related degradation. The most pertinent portion of this work, for the current study, is the exhaustive treatment of Track Quality Indexes (TQI) to measure geometric irregularities over time using specific test zones. Data were obtained from 360 miles of Conrail track over a four-year period (Fall 1978 to Fall 1982) to provide consecutive track geometry, maintenance and track data over time. The sophisticated track degradation modeling effort uses these data to generate degradation curves over time for various operating scenarios.

This research is complex, expensive, requires government funds and railroad cooperation. For the transit environment, the work is of limited immediate value, due to the current limitations on transit R & D funding as well as differences in the operating environment between railroad and transit (See previous section). Further, the MBTA does not currently have a rapid transit track geometry car to measure geometry over time. However, it does have such a car on order which will be capable of commuter rail and rapid transit operations.

The primary value of this research is to demonstrate how a track condition monitoring program could be established, based on TQI, if the resources and staff were available. A final point, the railroad equipment inventory reporting capability is much more extensive than that of the MBTA.

Bing (1984) expands the application of his track degradation model to analyze Amtrak's Northeast Corridor track quality over the October 1981 - September 1983 period. The procedure utilized in this study is similar to that which was developed in Bing (1983). Two primary operating conditions distinguish this study. The first concerns the traffic mix. Track degradation results from both passenger trains and freight consists. Different "test zones" (where track geometry data was obtained) support different mixes of passenger versus freight train tonnage, (See Table 5-1). These data could allow shared maintenance cost allocation between Amtrak and the freight user roads. Exhibit 5-1 shows track quality indexes, by test location, for wood and concrete ties as a function of traffic volume and maintenance cycle. These charts are elegant but this class of analysis is beyond the means of the MBTA due to lack of track geometry equipment and a location - specific track component inventory.

Love (1981) was an early author who recognized the underlying relationship between maintenance demand and maintenance supply, as well as the link between economic and engineering factors in assessing track quality. His unpublished thesis provides many high quality theoretical track performance curves (See Figures 5-1, 5-2 and 5-3) and formulas for scheduling maintenance activities:

$$PR = \frac{\text{DAMAGE REPAIRED}}{\text{TIME WORKED}}$$

This formula can be applied to the MBTA Special Track Program Control Reports by evaluating the number of feet of, for example, running rail installed in a particular location and using the total hours of labor the job required. Another useful performance measure developed by Love is to determine

Table 5-1

TONNAGE DATA

Test Zone	MP	Total/Passenger/Freight/Heavy Axleload: October 1981 – April 1982	April 1982 – September 1982	September 1982 – May 1983	May 1983 – September 1983
1	41 - 51	4.0/0.6/3.4/2.0	3.3/0.6/2.7/1.7	6.6/1.7/4.9/2.5	4.4/1.6/2.8/2.2
	51 - 57	8.6/2.7/5.9/4.0	7.1/2.2/4.8/3.4	9.8/3.1/6.6/5.1	5.2/1.7/3.5/2.6
	57 - 59.5	6.4/2.7/3.7/2.9	5.9/2.2/3.7/3.0	8.2/3.1/5.1/4.1	4.6/1.7/2.9/2.4
	59.5 - 60.5	18.9/2.7/16.2/14.3	14.6/2.2/12.3/10.7	17.1/3.1/14.0/12.0	4.2/1.7/7.4/6.3
	60.5 - 71	11.2/2.7/8.6/7.7	8.9/2.2/6.7/6.0	9.0/3.1/5.9/5.6	3.2/1.7/1.5/1.6
2	62 - 76	2.9/1.8/1.1/1.4	2.0/1.4/0.6/0.8	3.1/2.4/0.7/1.2	2.2/1.9/0.3/0.7
3	146-156	1.1/0.9/0.2/0.4	0.9/0.7/0.2/0.3	1.3/1.1/0.2/0.5	0.7/0.6/0.1/0.2
4	169-179	1.1/0.9/0.2/0.4	0.9/0.7/0.2/0.4	1.3/1.1/0.2/0.5	0.7/0.6/0.1/0.2
5	196-204	2.3/1.6/0.8/1.3	1.9/1.3/0.5/0.9	2.8/1.9/0.9/1.4	1.5/1.1/0.5/0.8
	204-214	1.9/1.6/0.3/0.8	1.8/1.3/0.5/0.9	2.0/1.9/0.7/1.5	1.5/1.1/0.5/0.8
	214-216	2.2/1.8/0.3/0.9	2.0/1.6/0.5/1.0	3.1/2.2/0.9/1.5	1.7/1.2/0.5/0.9
6	169-179	1.2/0.9/0.3/0.3	0.9/0.8/0.2/0.4	1.3/1.1/0.3/0.5	0.7/0.6/0.1/0.3

Source: Bing, et al, 1984

Exhibit 5-1

AMTRAK NORTHEAST CORRIDOR TRACK DATA
TEST ZONE 4

BOSTON DIVISION: MILES 169-179 TRACK 2
PERIOD: OCTOBER 1981 - SEPTEMBER 1982
SEPTEMBER 1982 - MAY 1983

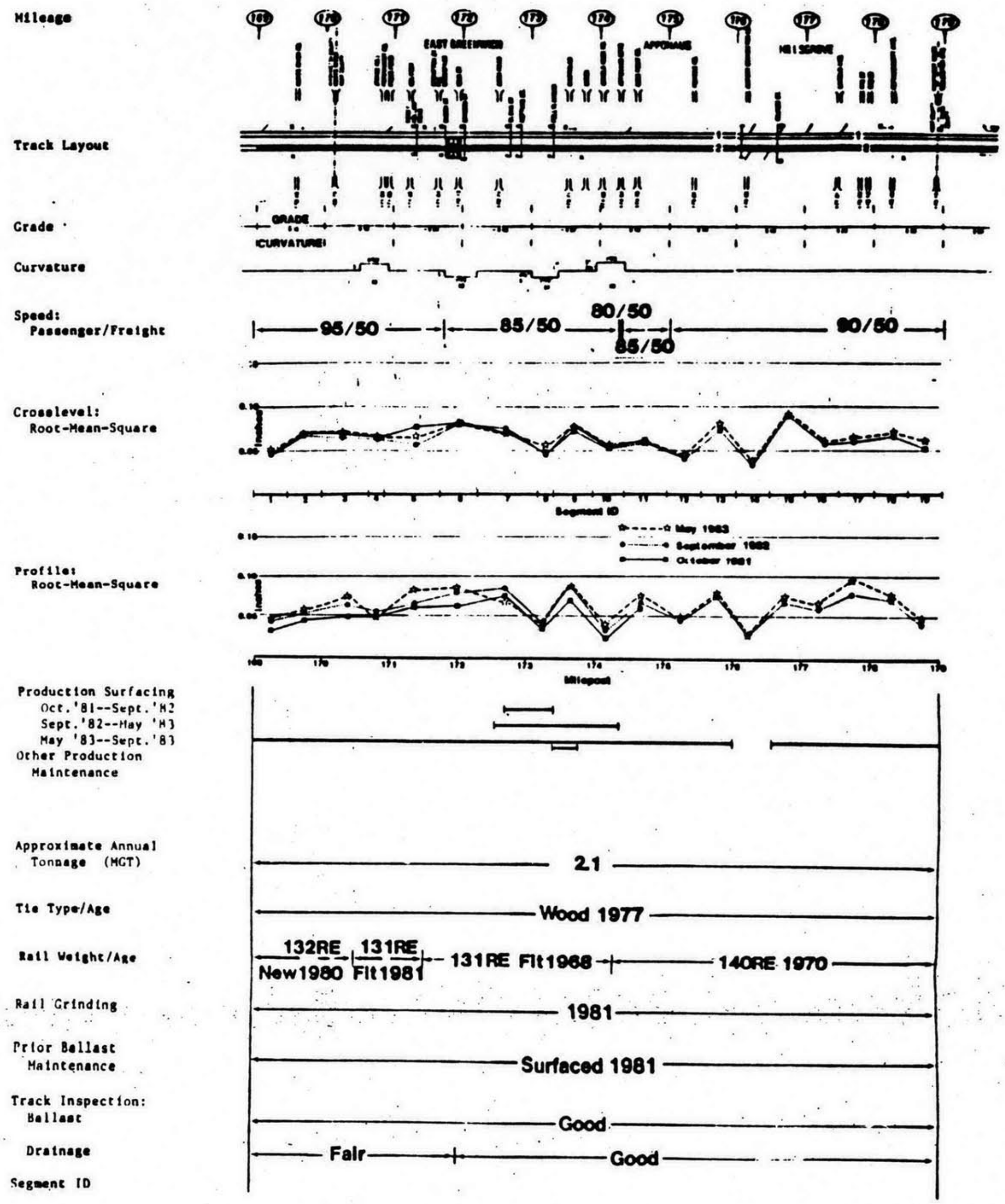
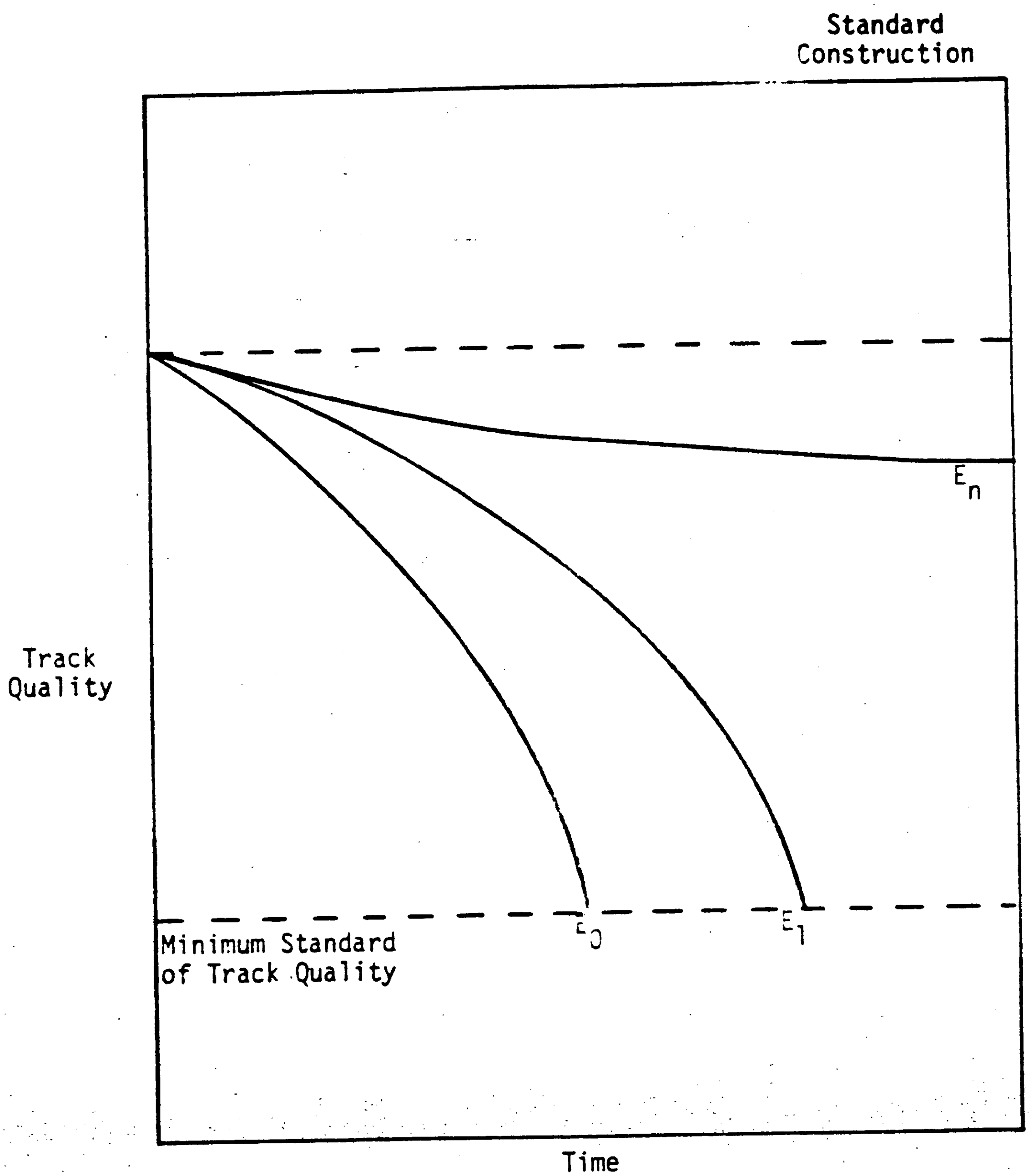


Figure 5-1



Hypothetical Track Deterioration Curves

Source: Love, 1981

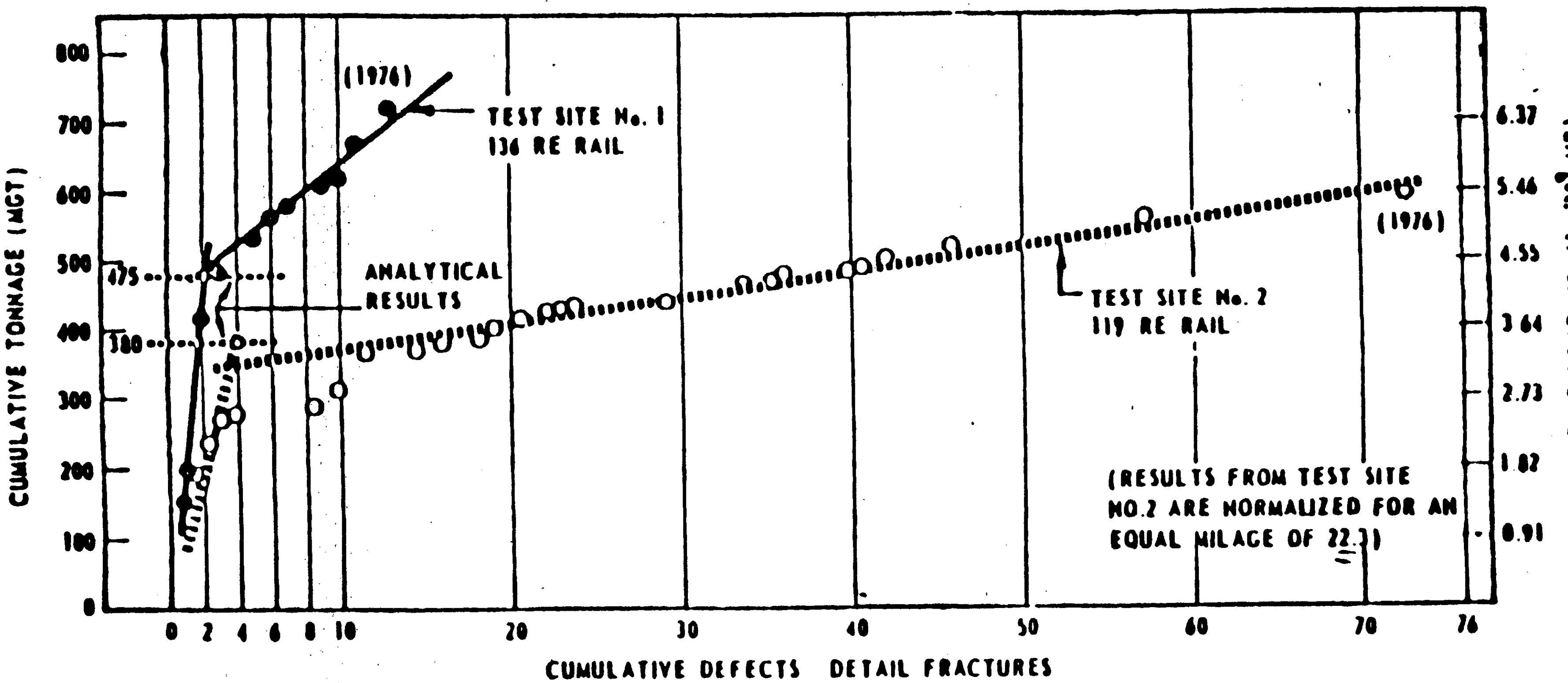
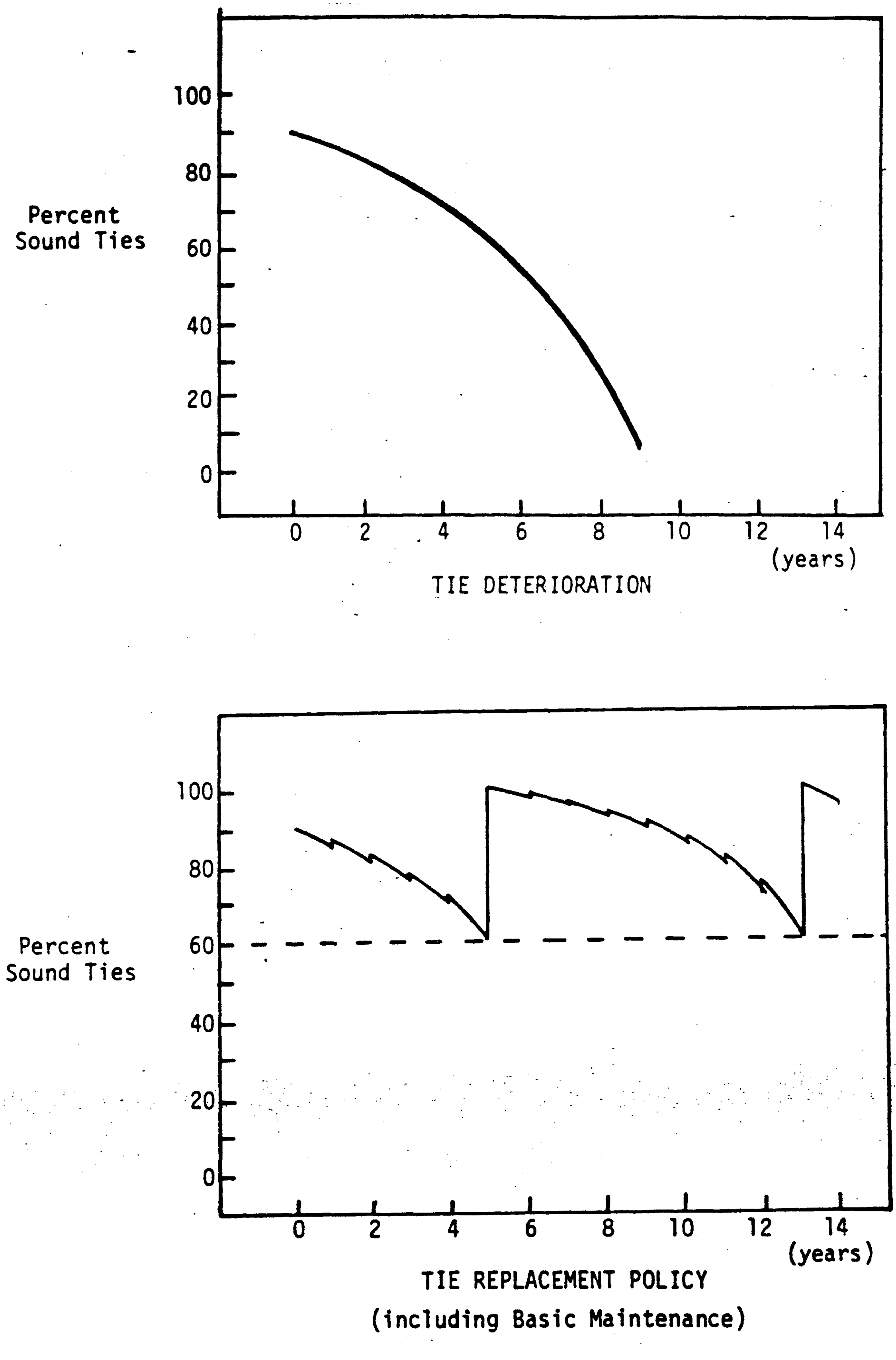


Figure 5-2

Source: Zarembski, A. M., "Fatigue Analysis of Rail Subject to Traffic and Temperature Loadings"

Figure 5-3



Source: Love, 1981

maintenance time requirements for a particular job:

$$T_{Productive} = \frac{\text{Maintenance Workload (MW)}}{PR}$$

Using this formula, the amount of time needed to finish a particular work element is equal to the amount of work defined by the workload and the real production rate. Love cautions that response time necessary to get a work gang to a job site will lower the productivity rate if the railroad distance is great, but, at the MBTA, geographical distances are not great, minimizing any adverse productivity impacts of crew response time to site.

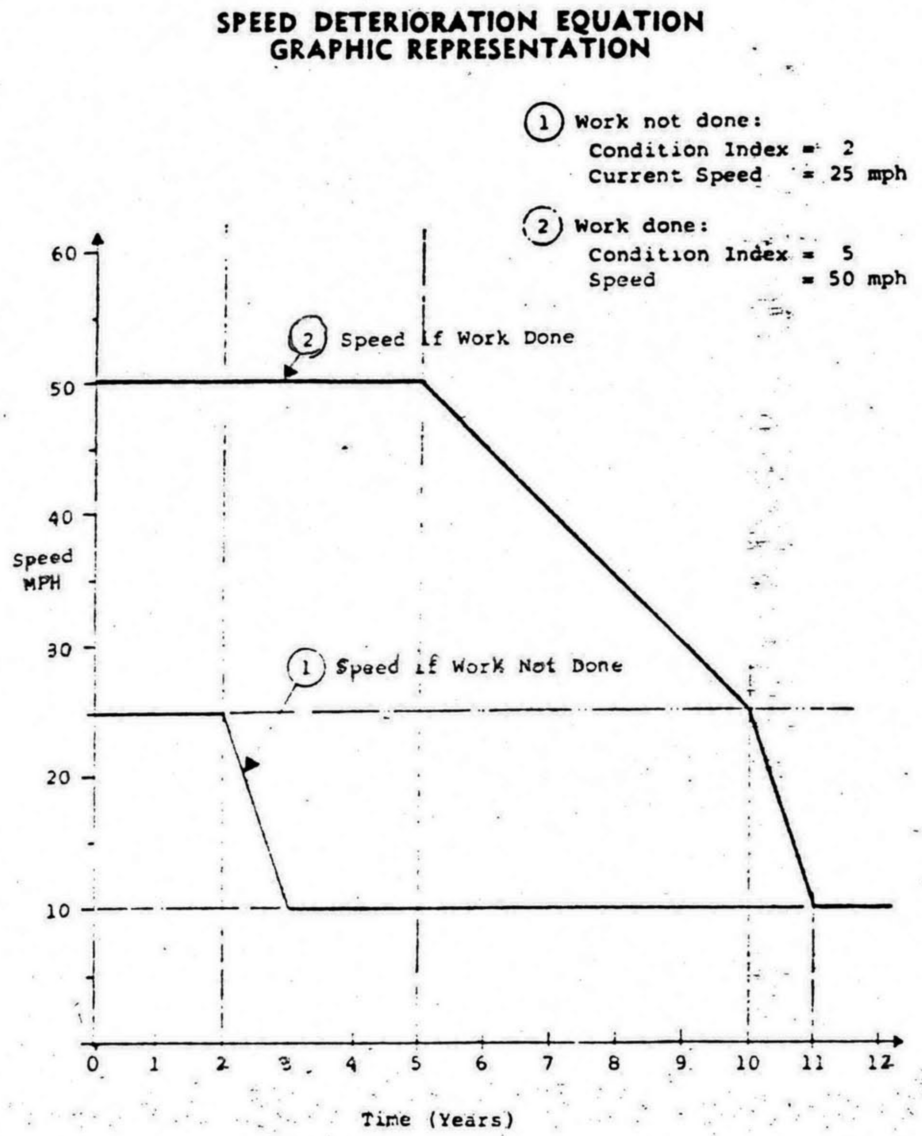
Further, Love's work provides a comprehensive railroad maintenance literature bibliography which is valuable in itself.

Financial Analysis

At Conrail (Folk, 1977) a financial investment analysis model is used to determine the timing of maintenance of way rehabilitation projects. Benefits of two operating scenarios are considered: comparison of projected operating costs if no rehabilitation project is performed versus operating costs over the same location if rehabilitation is performed. Consequently, savings are calculated based on increased train speed, fewer train derailments, and costs of rerouting trains if the track service quality is too low for certain fragile shipments. Exhibit 5-2 presents the speed/time curve used in the model if the rehabilitation project is done, and a second plot line if the work is not performed.

Speed-related savings, traffic density, safety, service factors and importance of the particular track segment are all assessed and weighted to calculate a discounted cash flow return on investment analysis:

Exhibit 5-2



Source: Folk, 1977

Assignment of Rehabilitation Points

factor	value	Rehab points
ROI	15-50%	0-50 pts.
	below 15%	eliminated from consideration
Volume-Road	0-40 million gross tons	0-30 pts.
Piggyback traffic-Road	0-5 million gross tons	0-5 pts.
Safety	track condition	0-10 pts.
Key routes	strategic importance	0-25 pts.
Maximum score for any one project		120 pts.

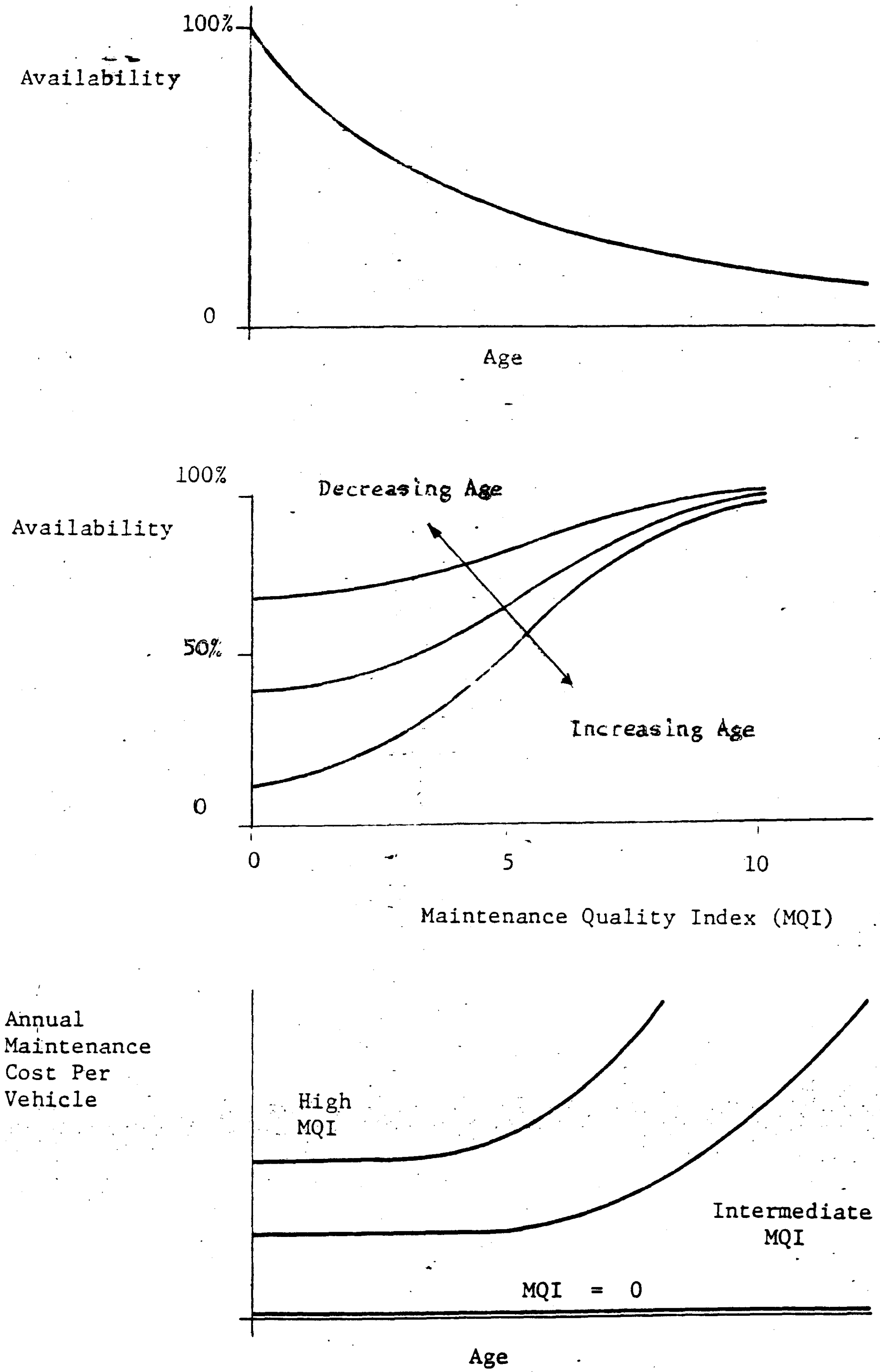
TABLE 5-2

Source: Folk, 1977, p. 438.

This rating and prioritization scheme could be adopted by the MBTA to schedule renewal activities by attaching MBTA-tailored attribute weights in the ranking formulation. However, a return-on-investment analysis may not be suitable for a public transit property which derives a good part of its capital budget from UMTA formula grant sources.

Moavenzadah,Markow and Brademeyer (1982) investigated bus fleet investment and maintenance in Egypt. The authors assess the Egyptian approach to vehicle-maintenance and make recommendations for improving maintenance. The authors use a simulation model to generate a wide variety of specific performance characteristics given a fixed set of inputs. Although the simulation approach is complicated, using the MIT Interim Operations Planning Model, it is able to accurately capture the complex structure of engineering and cost performance curves under a variety of maintenance policies (See Figure 5-4). Fleet maintenance

Figure 5-4



Structure of Maintenance Relationships

Source: Moavenzadeh, et al, 1982

policy is based on the simulated output of different maintenance policy cost projections. The concepts presented by this paper are, and represent, an analytical technique to strive for, although the calculations are generated with a mysterious "Black Box".

Similarly, Markow (1984) has expanded the simulation approach using the Interim Operations Planning Model to evaluate planning and management options in the rehabilitation of the Spanish National Rail System. Exhibit 5-3 shows the schematic approach used by Markow in the simulation model. Using a Maintenance Quality Index (MQI), the track performance and cost histories of two track maintenance policies are compared--one more intensive than the other (Figure 5-5). Hence, management can consider the best option with budgetary constraints.

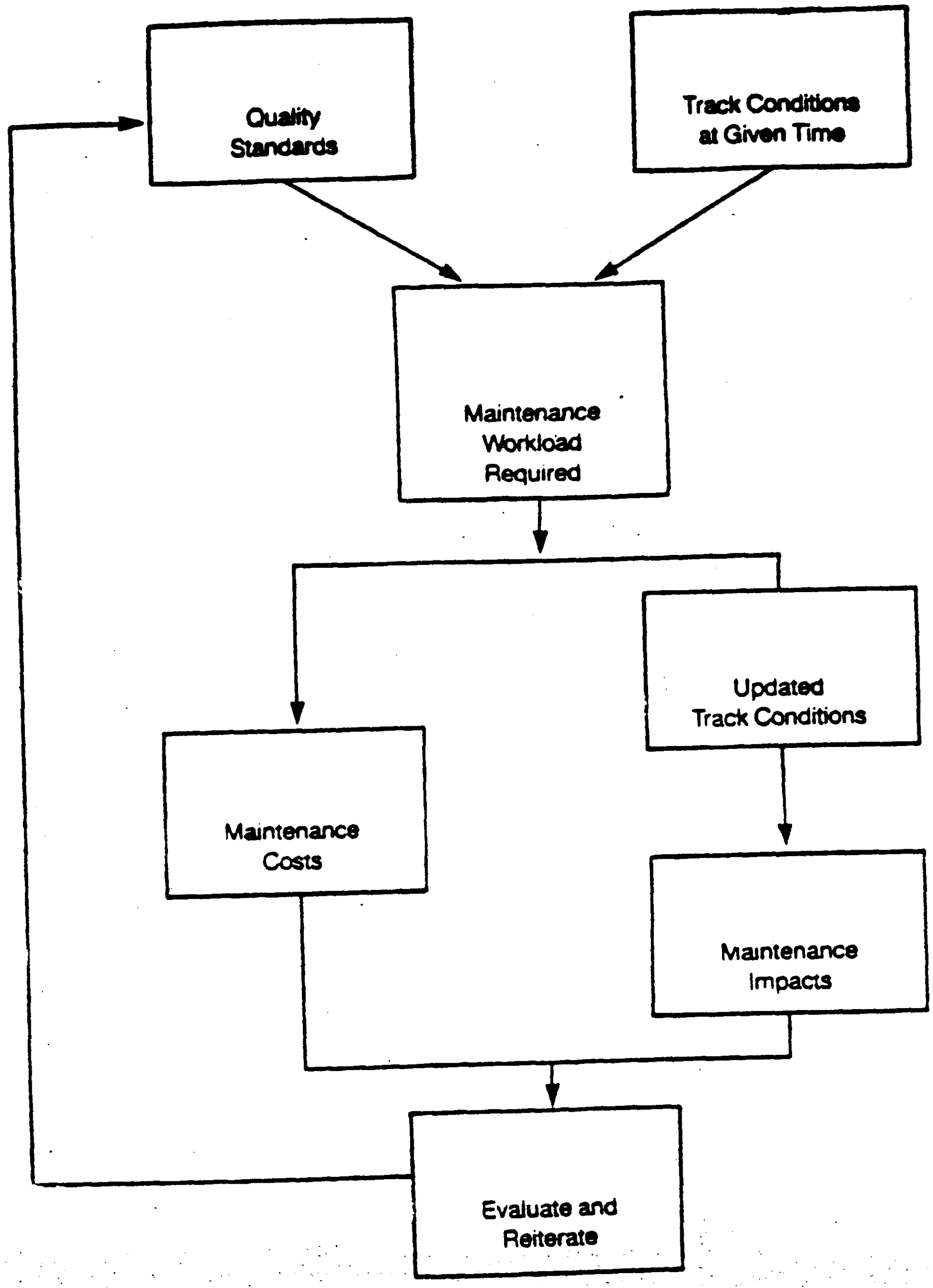
The simulation approach would be desirable to establish maintenance policy at the MBTA, as well as the timing of major and minor preventive maintenance cycles; however it does require good location-specific maintenance history cost data. This consideration precludes any near-term development at the E & M Department.

Economic Analysis

A series of FRA-sponsored track rehabilitation and maintenance research projects was concluded in 1979/1980. These studies had the same general objectives as the track degradation modeling efforts previously reviewed (Bing, 1979, 1980); they are intended to improve railroad track quality and safety. Specifically, four final reports are evaluated, including:

1. A MITRE study which rank-ordered track system problems by component and subcomponent
2. A PBQ & D study which used loosely structured interviews [cont.]

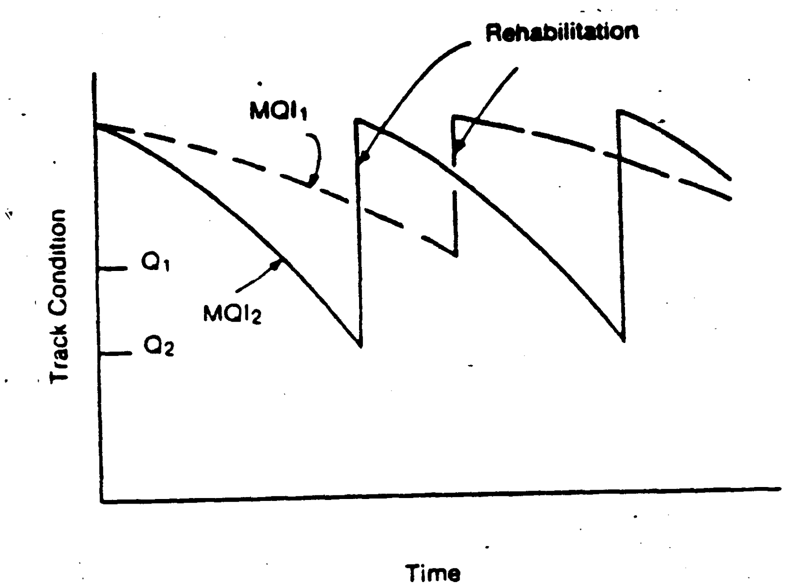
Exhibit 5-3



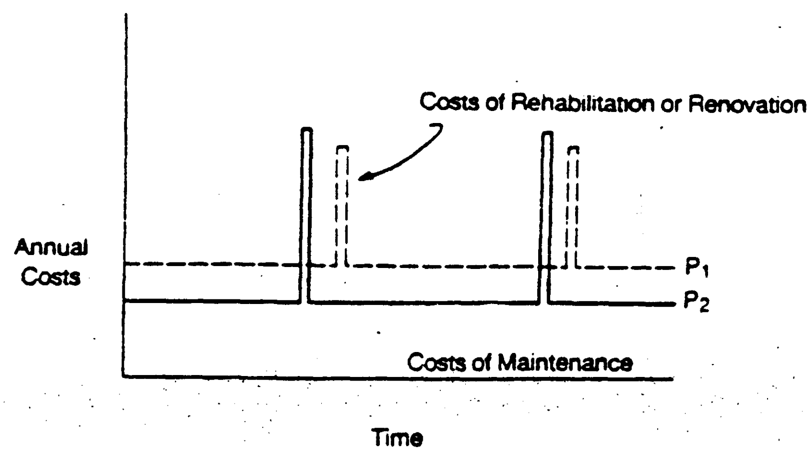
Approach to Demand-Responsive Maintenance Management

Source: Markow, 1984

Figure 5-5



Simulation of Track Performance for Two Maintenance Policies (MQI) and Two Rehabilitation Policies (Q)



Cost Histories for Two Maintenance Policies (P)

Source: Markow, 1984

with railroad personnel to rank-order 78 track system problems

3. A unified industries study which evaluates the feasibility of applying mechanized track renewal principles to U.S. railroads
4. A survey of track renewal machines and systems in Europe and North America, also conducted by Unified Industries

These studies are included in the economic analysis section because they pertain to maintenance productivity and cost areas. Two separate studies are presented which adapt econometric principles to model track maintenance and track safety.

After 1976, when the "3-R" Act was passed, the FRA Improved Track Structures Research Program began to improve track system safety and cost-effectiveness. Two studies were commissioned, both to identify alternative R & D areas for improved track performance and operation, and to rank-order those attributes and develop an index for objective cross-sectional evaluation.

The MITRE Study (1980) concentrated on track rehabilitation while the PBQ & D Study emphasized track maintenance. The MITRE approach developed a system of problem identification and rank-ordering by compiling a list of track problems (from interviews and surveys) classified by track component (See Table 5-3 and Table 5-4). These problem areas are grouped into major categories, called subprograms, and a subsequent valuation analysis is calculated for each subprogram using benefit-cost ratios and other measures (Table 5-5).

The PBQ & D uses a separate set of evaluators to rank subjective maintenance problems. Strictly speaking, this changes the rank-order weighting used in each study. Consequently, subprogram values calculated for each

Table 5-3

RANK-ORDERED TRACK SYSTEM PROBLEMS--MITRE STUDY

Rank	Problems	Score
1.	Inadequate Track Structure Cost/Performance Data	1039.0
2.	Excessive Rail Wear	200.7
3.	Insufficient Cost/Performance Information on Ballast	197.5
4.	Excessive Longitudinal Rail Stress	189.4
5.	Inadequate Concrete Tie Performance	172.3
6.	Inadequate Maintenace of Way Methods	161.1
7	Inadequate Performance of Spikes/Plates as Fasteners	151.5
8.	Insufficient Cost/Performance Data--Proper Rail Selection	146.9
9.	Premature Rail Failure	146.3
10.	Insufficient Information about Subgrade Performance	122.1
11.	Inadequate Field Welding Techniques	118.3
12.	Unknown Cost/Performance of Subgrade Improvement Methods	108.8
13.	Excessive Rail Plastic Flow Defects	97.3
14.	Inadequate Concrete Tie Fastener Design	89.9
15.	Inadequate Methods for Subgrade Improvement	83.9
16.	Excessive Ballast Degradation	81.6
17.	Excessive Ballast/Subgrade Interactions (Pumping)	81.0
18.	Track System R&D Results Not Properly Disseminated	79.8
19.	Excessive Wood Tie Degradation	77.8
20.	Bolt/Bolt Hole Problems	75.5
21.	Inadequate Wood Tie Renewal Methods	69.8
22.	High Concrete Tie Initial Installation Costs	67.6
23.	Inability to Determine Rail Stresses in the Field	62.0
24.	Unknown Anchor Effectiveness/Performance	60.9
25.	Inadequate Field Rail Flaw Detection	60.5
26.	Unknown Future Cost/Availability of Wood Ties	55.4
27.	Insufficient Cost/Performance Data--Optimum Wood Tie Utilization	54.1
28.	Insufficient Knowledge about Cost/Performance of Special Trackwork	53.8
29.	Inadequate Frog Maintenance Methods	53.2
30.	Track Geometry Problems	46.5
31.	Insufficient Information--Cost/Performance of Innovative Wood-Base Ties	44.2
32.	Excessive Switch Wear	44.2
33.	Insufficient Cost/Performance Data--Innovative Wood Tie Fasteners	37.4
34.	Inadequate Subgrade Assessment Techniques	36.5
35.	Insufficient Cost/Performance Data--Wood Tie Selection	35.9
36.	Inadequate Concrete Tie Cost/Performance Data	34.7
37.	Excessive Ballast Fouling	33.0

Source: Zobrak, 1980

Table 5-3
(continued)

RANK-ORDERED TRACK SYSTEM PROBLEMS--MITRE STUDY

Rank	Problems	Score
38.	Inadequate Slope Stabilization Methods	29.6
39.	Insufficient Information on the Causes of Railway Accidents	27.5
40.	Inadequate Stock Rail Maintenance Methods	26.0
41.	Inadequate Ballast Maintenance/Rehabilitation Methods	25.3
42.	Inadequate MOW Methods at Crossings	24.7
43.	Inadequate Joint Maintenance Methods	24.6
44.	Cost/Benefits Associated with Tie Plate Area Unknown	23.0
45.	Subgrade Heaving	21.9
46.	Inadquate MOW Methods at Switches	19.5
47.	Inadequate Methods for Evaluating In-Situ Track	17.9
48.	Unknown Cost/Performance	17.4
49.	Inadequate Bonded Joint Maintenance	17.3
50.	Inadequate Field Weld Inspection Techniques	16.6
51.	Track System R&D Goals Not Clear--Gov/Public/RR Conflicts	15.6
52.	Premature Joint Bar Breakage	15.1
53.	Unknown Effects of Track Design/Irregularities on Rail Vehicles	14.3
54.	High Cost of Insulated Joint Installation Methods	13.4
55.	Inadequate Cost/Perf Data--Optimum Joint Bar for Conditions	12.7
56.	Inadequate Anchor Installation Methods	12.7
57.	Line Speed/Yard Capability Not Compatible	12.6
58.	Inadequate Field Joint Bar Flaw Detection	11.1
59.	Excessive Joint Bar Wear	10.6
60.	Inadequate Vegetation Control Methods	9.5
61.	Inadequate Methods for Maintaining Track Geometry at Spec Trackwork	8.6
62.	Inadequate Bolted Insulated Joint Performance	7.1
63.	Inadequate Bonded Joint Performance	5.7
64.	Too Much Curved Track (Line Modification Needed)	3.8
65.	Insufficient Information about Non-Conventional Structures	3.2
66.	Unrealistic Government Track Standards Regulatory Action	2.1

Source: Zobrak, 1980

Table 5-4

RANK-ORDERED TRACK SYSTEM PROBLEM--PBQ&D STUDY

Rank	Problem	Score
1.	Inadequate Performance of Spikes/Plates as Fasteners	366.9
2.	Excessive Rail Wear	290.4
3.	Inadequate Technique for Evaluating Remaining Bridge Life	244.6
4.	Insufficient Cost/Performance Information on Ballast	221.7
5.	Inadequate Wood Tie Renewal/Disposal Methods	214.0
6.	Excessive Rail Plastic Flow Defects	191.1
7.	Inability to Determine Rail Stresses in the Field	168.2
8.	Unknown Cost/Performance of Subgrade Improvement Methods	168.2
9.	Inadequate Methods for Subgrade Improvement	168.2
10.	Premature Rail Failure	142.9
11.	Inadequate Track Geometry Measuring Methods	137.6
12.	Inadequate Field Rail Flaw Detection	129.9
13.	Inadequate Track Structure Cost/Performance Data	107.0
14.	Excessive Longitudinal Rail Stress	99.4
15.	Excessive Ballast/Subgrade Interactions (Pumping)	99.4
16.	Inadequate Bridge Repair/Maintenance Techniques	91.7
17.	Inadequate Method of Waterproofing Bridge Decks	91.7
18.	Inadequate Field Welding Techniques	84.1
19.	Excessive Switch Wear	84.1
20.	Inadequate Maintenance of Way Methods	84.1
21.	Excessive Wood Tie Degradation	84.1
22.	Unknown Anchor Effectiveness/Performance	76.4
23.	Inadequate Method of Detecting Fatigue Cracks in Steel Bridges	76.4
24.	Inadequate Bolted Insulated Joint Performance	68.8
25.	Inadequate Methods of Tunnel Drainage	68.8
26.	Excessive Frog Wear and Failure Rate	61.1
27.	Unknown Future Cost/Availability of Wood Ties	53.5
28.	Unknown Limits of Switch Point Wear and Condition	53.5
29.	Inadequate Bridge Rating Procedures	53.5
30.	Deficiencies in Bridge Inspection Methods/Tools	53.5
31.	Excessive Ballast Fouling	49.7
32.	Inadequate Subgrade Assessment Techniques	45.9
33.	Insufficient Track Availability for Maintenance	45.9
34.	Inadequate Concrete Tie Fastener Design	45.9
35.	Track System R&D Results Not Properly Disseminated	38.2
36.	Insufficient Cost/Performance Data-Optimum Rail Length	30.6
37.	Non-Standardization of Track Components	30.6
38.	Excessive Ballast Degradation	26.8
39.	Excessive Eye-Bar Wear in Bridges	22.9
40.	Inadequate Bridge Expansion Bearing Performance	22.9

Source: Zobrak, 1980

Table 5-4 (CONTINUED)

RANK-ORDERED TRACK SYSTEM PROBLEM--PBQ&D STUDY

Rank	Problem	Score
41.	Inadequte Performance of Bridge Expansion Joints	22.9
42.	Excessive Concrete Spalling on Bridges	22.9
43.	Bolt/Bolt Hole Problems	22.9
44.	Inadequate Joint Maintenance Methods	22.9
45.	Inadequate Joint Performance at Turnouts	22.9
46.	Insufficient Cost/Performance Data--Innovative Wood Tie Fasteners	22.9
47.	Inadequate Timber Tie Installation Methods	22.9
48.	High Concrete Tie Initial/Installation Methods	22.9
49.	Inadequate Concrete Tie Cost/Performance Data	22.9
50.	Inadequate MOW Methods at Crossings	22.9
51.	Inadequate Tunnel Inspection Methods/Tools	22.9
52.	Insufficient Cost/Performance Data--Proper Rail Selection	15.3
53.	Inadequate Rail Lubrication Methods	15.3
54.	Premature Joint Bar Breakage	15.3
55.	Insufficient Information about Subgrade Performance	15.3
56.	Inadequate Slope Stabilization Methods	15.3
57.	Insufficient Cost/Performance Data--Optimum Wood Tie Utilization	15.3
58.	Inadequate Wood Tie Cost/Performance Data	15.3
59.	Inadquate Protection from Blowing Soil	15.3
60.	Inadequate Methods of Preserving Wood Decks on Bridges	15.3
61.	Insufficient Knowledge of CWR Behavior on Bridges	15.3
62.	Inadequate Techniques for Specific Tunnel Repairs	15.3
63.	Inadequate Bridge Pier Protection Methods	7.6
64.	Inadequate Methods of Protection of Bridge Concrete Surfaces	7.6
65.	Inadequate Methods for Fireproofing Bridge Decks	7.6
66.	Inadequate Fire Protection for Timber Tunnels	7.6
67.	Insufficient Information--Cost/Performance of Innovative Wood-Base Ties	7.6
68.	Snow and Ice in Switch Points	7.6
69.	Excessive Track Damage from Anchors Due to Derailments	7.6
70.	Damage to Bridges from Loose Loads	7.6
71.	Insufficient Information about PSC Bridge Spans	7.6
72.	Insufficient Cost/Performance Date on Bridge Steel Protective Coating	7.6
73.	Excessive Spalling of Tunnel Rock or Concrete Lining	7.6
74.	Inadequate Tunnel Track Maintenance Methods	7.6
75.	Insufficient Knowledge about Cost/Performance of Special Trackwork	2.3

Source: Zobrak, 1980

Table 5-5

VALUES OF SUBPROGRAM EVALUATION MEASURES--MITRE STUDY

Subprogram	Benefits ($'s In Millions)	R&D Costs ($'s In Millions)	Benefit-Cost Ratio	Safety Impact (Accidents Prevented)	Capital Savings ($'s In Millions)	R&D Time (Years)	Other Impacts	Prob. Of Success
A	261.4	$5.70	45.9	252	144.0	7.0	1.85	0.67
B	49.4	1.30	37.9	114	11.3	3.8	1.45	0.46
C	1.8	1.40	1.3	1	- 3.0	6.2	1.61	0.51
D	533.8	1.60	340.0	83	-37.8	4.5	0.71	0.31
E	1.3	0.50	2.6	6	0.2	3.7	0.90	0.54
F	20.6	0.32	65.4	6	10.6	2.2	0.41	0.60
G	422.1	0.62	680.8	0	232.5	3.9	0.31	0.22
H	3.5	0.13	26.9	7	- 1.6	4.8	0.73	0.66
I	6.0	0.71	8.4	0	3.3	3.7	0.29	0.42
J	6.7	1.70	3.9	2	- 4.8	6.0	0.96	0.42
K	3.2	0.89	3.6	0	- 4.7	4.3	1.21	0.44
L	320.4	0.41	781.5	0	321.9	3.7	0.80	0.55
M	9.5	1.90	5.0	0	- 9.3	6.1	0.86	0.52

Source: Zobrak, 1980

study are not directly comparable.

Although the specific track components used at the MBTA may differ from the railroad-oriented rank-ordering of problem areas, the analytical approach is applicable for transit track. The approach used in these studies is largely based on personal interview; a more objective measure could calculate a probability of defect incidence based on historical, location-specific performance. The point here is that cost-benefit analysis could be used at the "T" to develop maintenance or renewal for the project ranking system. This concept will be developed in the next chapter.

Two Unified Industries (1979, 1980) studies concentrate on surveying track renewal systems and evaluating the feasibility of employing the European method of track renewal systems to U.S, railroads. The first study provides a review of U.S. current practices, where spot maintenance predominates. Track renewal machines are reviewed including the Canron machine Plasser Machine, and the Suz 250 (See Figures 5-6 and 5-7) as well as the gantry crane machine (Figure 5-8). Several European case studies follow.

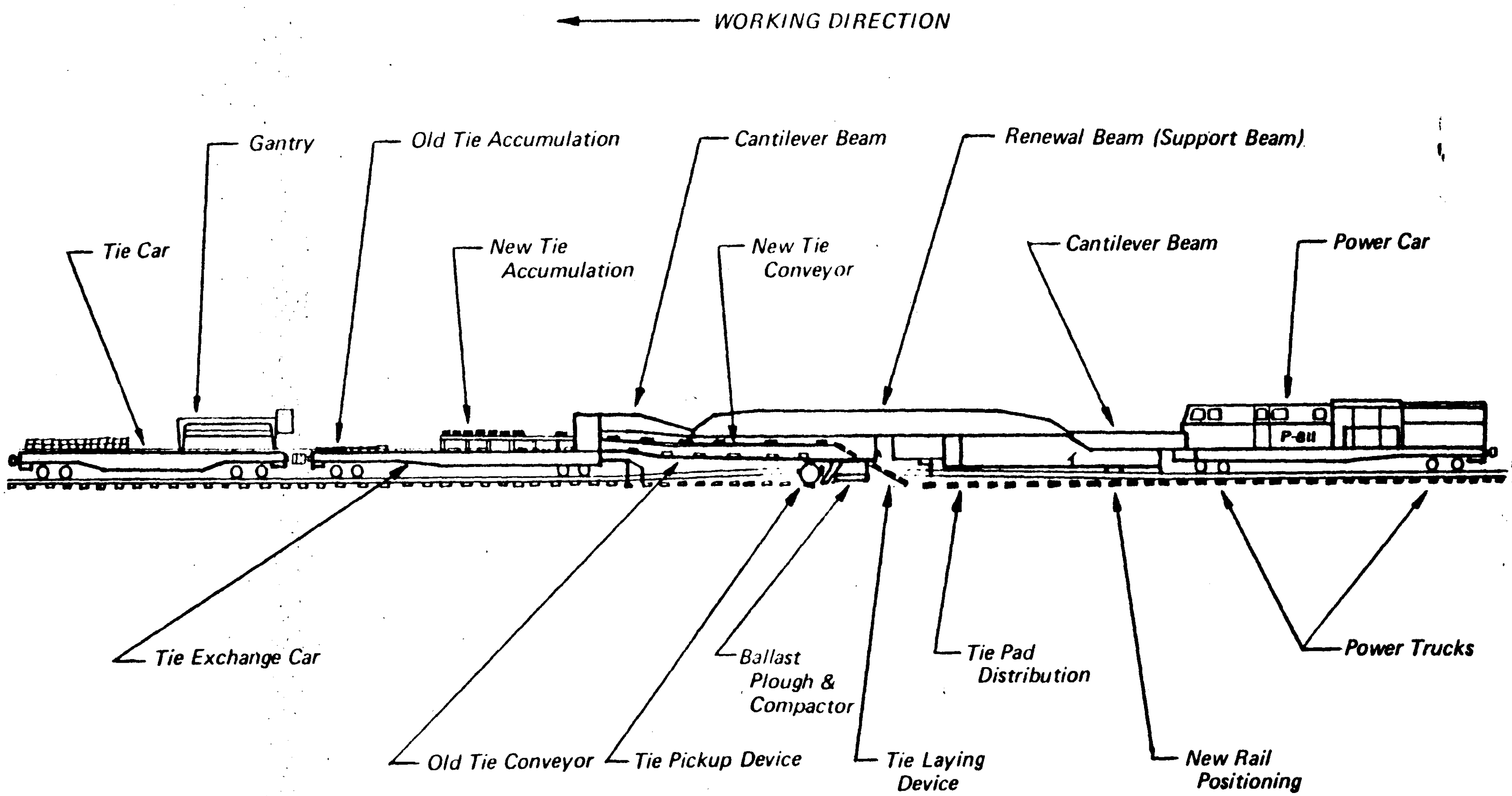
Automated track renewal machines are certainly transferrable, and in use, at many U.S. mainline railroads. However four constraining factors impede their use at MBTA RoWs:

1. Clearance restrictions
2. Lack of transit-suitable equipment suppliers
3. Absence of the potential for economies of scale at relatively small transit properties
4. Limited capital to acquire equipment

Further this technology may violate union work rules and clauses, but not those of contractors.

The second Unified Industries study develops an economic framework to

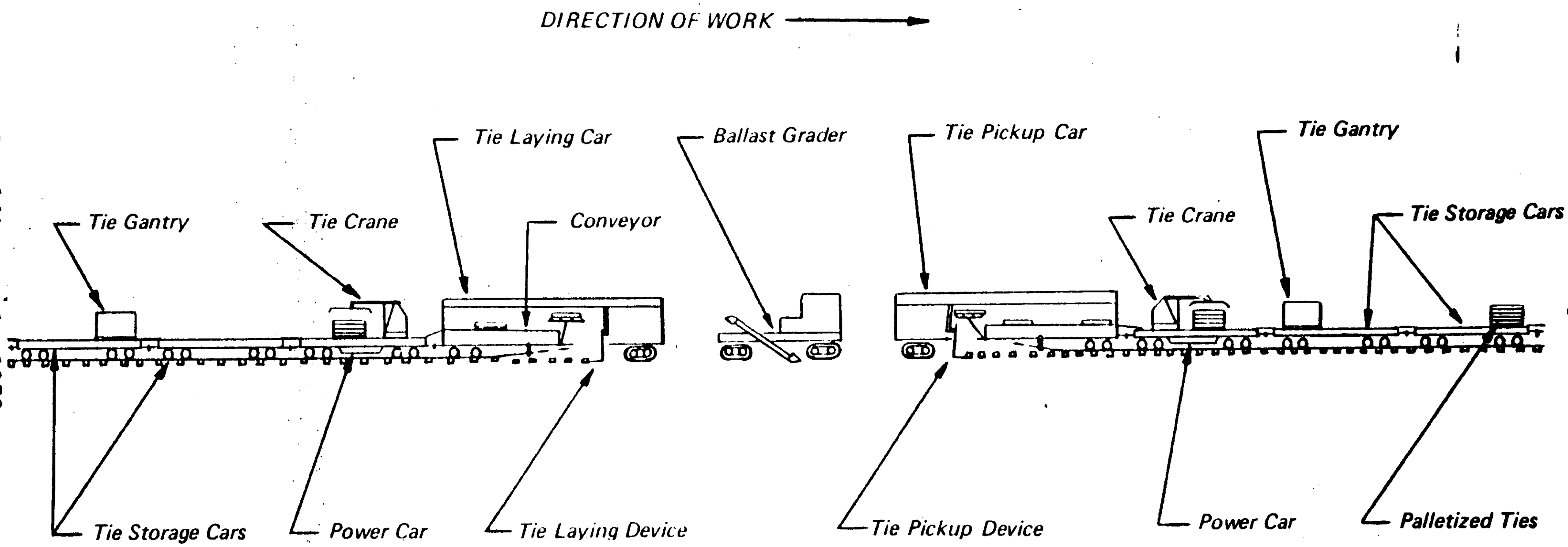
Figure 5-6



CANRON P-811 TRACK RENEWAL MACHINE

Source: Cataldi, et al, 1979

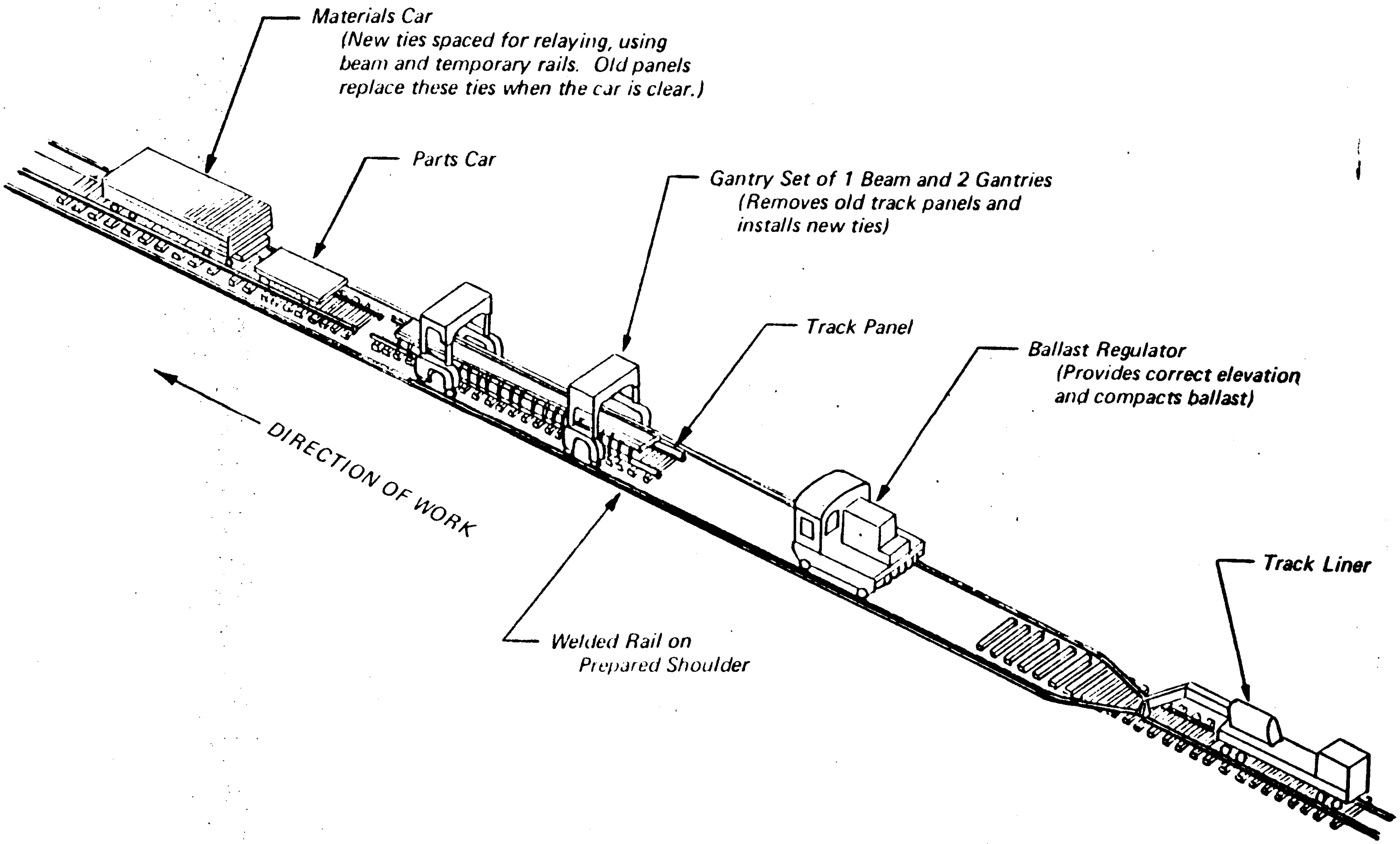
Figure 5-7



PLASSER AND THEURER SUZ 350 TRACK RENEWAL TRAIN

Source: Cataldi, et al, 1979

Figure 5-8



RMC/SECMAFER GANTRY SET TRACK RENEWAL MACHINE

Source: Cataldi, et al, 1979

evaluate the costs and benefits of track renewal systems versus prevailing spot maintenance methods. The method, rather than the results, could be used at the MBTA. It identifies unit costs per-mile for each major operation for spot maintenance and track renewal. This approach is exactly the one which the author would have adopted at the "T" if data were available for materials installed, labor, equipment maintenance, transportation (negligible in transit), equipment leases and capital recovery. Further, wood tie or rail re-use could be considered as a credit to the total project cost.

It is possible to perform parts of this type of analysis at the MBTA using Special Track Program data. The comparison is, however, impossible since no one knows the exact cost of MBTA spot repairs by activity and location. This is a correctible deficiency, after the MIS is implemented for maintenance project control.

Mauri, Ismail, Kim, and Skinner (1980) developed a linear regression model to relate MoW expenditures with train-derailments. As derailments rise, the amount and degree of deferred maintenance is estimated for five of the "safest" U.S. railroads. The dependant variable is the number of freight train derailments in a given year. Independant variables are defined by freight-train hours (a control) per train-miles of track maintained by each railroad, and present-value of 15 years worth of maintenance spending on mainline track. A cross-sectional analysis is made for various railroads to determine relative deferred maintenance levels. As real expenditure goes up, derailments go down (the coefficient is -.506 for the expenditure variable).

This study provides a method of evaluating gross changes in system-wide derailments based on maintenance expenditure. Time-series data were not used, hence it is difficult to determine micro-scale location-specific changes in track maintenance levels over time. The model is useful to show that there ~~is~~ a relationship between spending and performance, but has limited application for resource allocation within a maintenance budget.

Thomopoulous (1966) adapted a step-wise regression procedure to evaulate the relation between various expenditure codes (track defects) and track curvature, gradient, traffic density, inertia, freight speed, and RoW age (Figure 5-9). Plots presented in the figure use the variable E_{TRSB} on the Y axis. This variable represents the combined expenditures of ties, rail, surface, and ballast elements over a 36 month period for 42 distinct test miles on the former Baltimore & Ohio (now CSX Corporation) Railroad Table 5-6 The specific reporting codes are presented in Table 5-7. and grouped by job type.

The procedure utilized is excellent and of primary relevance to this study. It enables a manager to determine the impact of spending by specific maintenance activity on track performance. This approach could be applied to MBTA transit track performance if two conditions were met:

1. Expenditures by maintenance activity area were normalized according to the actor performing the work; e.g. contractor or in-house track gangs, and
2. expenditures were reported on an aggregate unit-mile basis for combined spot and programmed maintenance.

It would also be of interest to test similar maintenance expenditure codes separately, e.g. spot versus production tamping.

Table 5-6

Characteristics of Test Miles

Test Miles	Curvature	Gradient	Traffic Density	Inertia	Freight Speed	Age
1	.00	.00	1.3	38.70	45	22
2	.92	.40	1.3	38.70	45	15
3	.57	.28	1.3	65.50	45	10
4	.00	.24	1.3	89.00	47	7
5	.00	.00	5.1	49.86	59	19
6	.00	.00	5.1	65.60	59	13
7	.57	.56	11.5	65.60	60	5
8	.41	.61	11.5	65.60	60	7
9	.10	.30	8.0	65.60	60	4
10	.19	.67	8.0	65.60	60	8
11	.00	.00	8.0	65.60	60	8
12	.00	.00	9.1	25.70	60	8
13	.48	.46	9.1	65.60	60	4
14	.29	.42	9.1	89.00	60	4
15	.00	.00	48.5	88.20	55	9
16	.50	.00	48.5	88.20	55	4
17	.00	.00	36.2	88.20	60	5
18	.00	.00	36.2	88.20	60	6
19	.19	.00	41.3	88.20	55	4
20	.24	.00	41.3	88.20	55	8
21	.09	.00	41.3	88.20	55	4
22	.00	.00	16.6	88.20	40	6
23	2.62	.00	20.7	88.20	40	6
24	.46	.00	34.0	97.00	50	5
25	.50	.00	34.0	97.00	50	5
26	1.11	.00	16.8	88.20	50	5
27	2.88	.00	34.0	97.00	35	4
28	1.56	.24	39.2	88.20	40	5
29	1.48	1.04	39.2	88.20	40	6
30	.09	.60	39.2	97.00	40	5
31	2.55	.00	39.2	97.00	40	4
32	3.46	.00	39.2	97.00	40	4
33	1.74	1.40	9.2	65.60	40	7
34	2.13	.60	9.2	88.20	40	4
35	2.39	.24	11.2	88.20	50	8
36	2.39	.24	29.4	88.20	50	4
37	1.83	.80	5.1	88.20	50	4
38	.72	.00	5.1	65.60	50	8
39	.12	.00	26.5	88.20	50	4
40	.33	.35	26.5	88.20	50	4
41	.08	.00	10.1	89.00	50	8
42	.18	.00	10.1	65.50	50	9
Average	.80	.25	20.9	78.83	50.4	6.9

Table 5-7

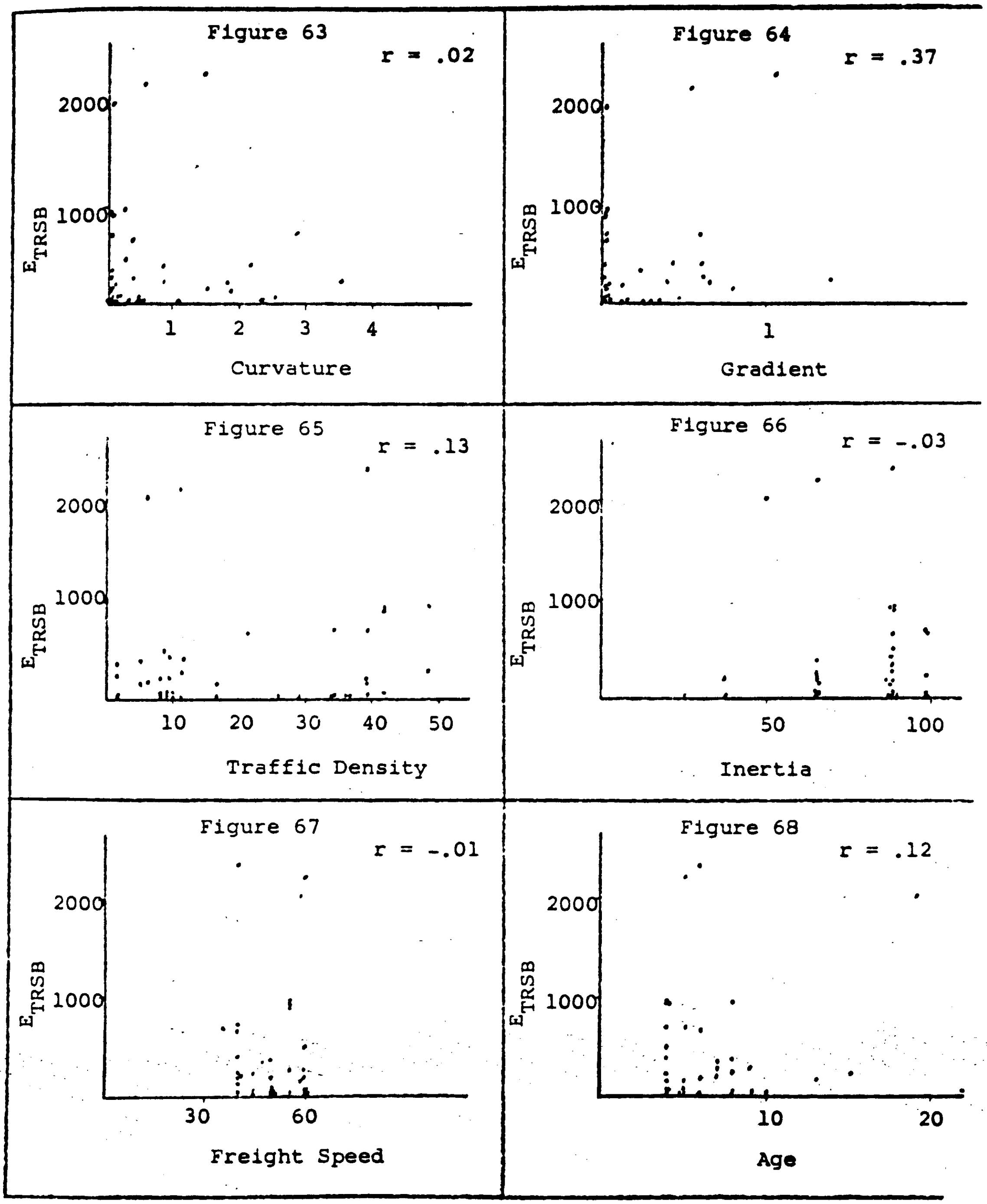
Categorization of Expenditure Codes Reported

Code	Description
	Tie Applications (T)
130	Cross ties - main line (material)
134	Install cross ties - main line
135	Install cross ties - side track
136	Install switch ties
137	Handle and unload cross ties
	Rail Applications (R)
154	Install new rail-welded
157	Install relay rail-jointed
162	Install other track material
163	Weld rail ends (2 per joint)
169	Handle rail and other track material-welded
171	Transpose or turn rail
172	Rail lubricators - fill, maintain, install
173	Tighten bolts
174	Repairs to tracks damaged by derailment
	Ballast and Surface Applications (SB)
105	Unload ballast
185	Line and surface track - main line
187	Spot surface - smooth track
	Miscellaneous Roadway Maintenance (M)
115	Clean ballast
116	Clear or kill weeds in track
117	Clean yard tracks
118	Remove slides and washouts
119	Patrol tracks
123	Clean ditches and drains
124	Remove weeds and brush
	Other Applications or Maintenance (O)
085	Install switch heater
202	Other repair - stations
211	Fences, snowsheds and signs
25[illegible]	Auto signal (incl. CTC and intrlk) - general
256	Auto signal (incl. CTC and intrlk) - track dept.
28[illegible]	Slide detector

Source: Thomopoulos, 1983

Figure 5-9

Scatter Plots of E_{TRSB} and Characteristics



Source: Thomopoulos, 1966

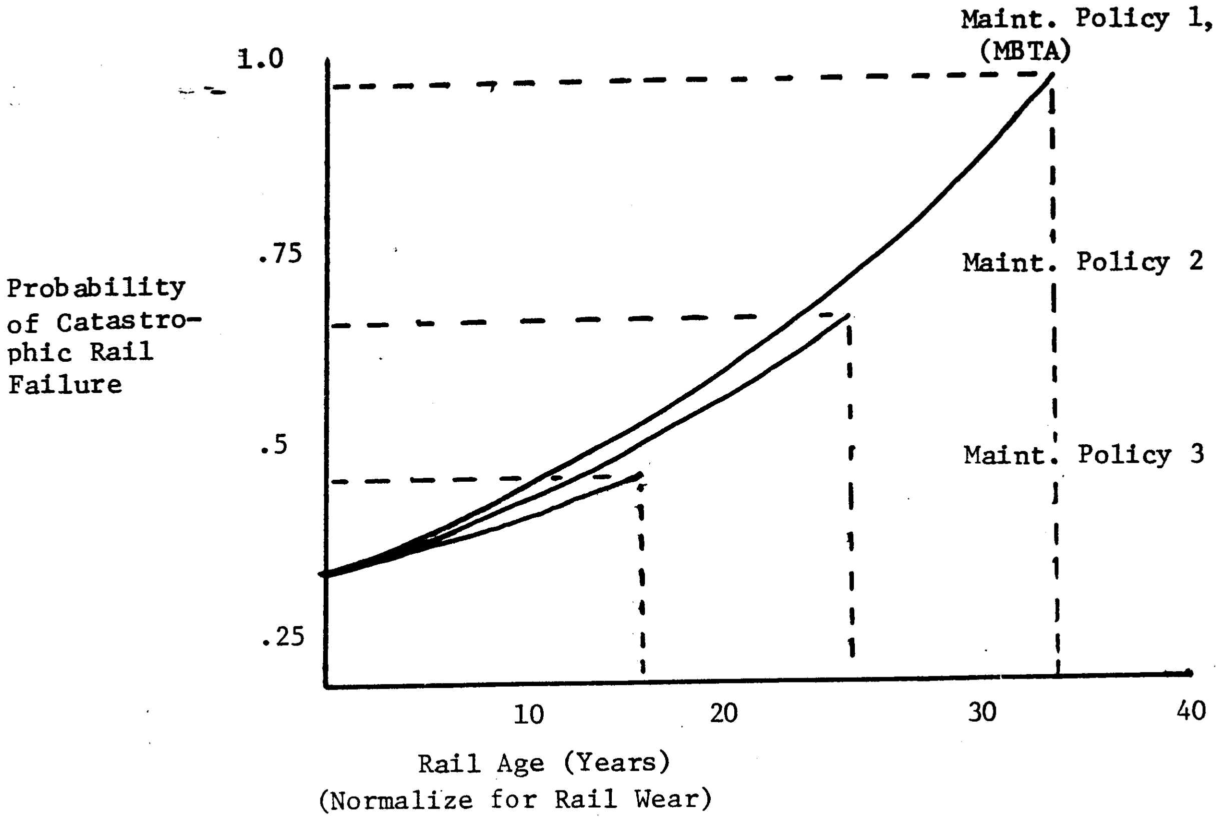


TABLE 6-1: Rail Failure versus Time as a Function of Maintenance Policy

This figure may not reflect the exact shape of the family of failure curves presented. It is intended as a conceptual guide to delineate where MBTA maintenance policy is depicted relative to these hypothetical failure curves. Policy 1 represents the least intensive maintenance policy: A change-out rail when it fails catastrophically. There are three management options at this point. 1) Demote track class and run trains at a lower maximum speed increasing trip time, and 2) invoke a temporary speed restriction until the road gang permanently changes-out broken rail segment, and 3) implement an intensive maintenance policy such that the probability of catastrophic failure is low (.4-.5) and relative P.M. costs are high, but predictable.

Evolution of Maintenance Policy and Standards

In 1964, legislation was enacted in Massachusetts which enabled the buy-out and subsequent takeover of the failing Metropolitan Transit Authority (MTA). Consequently, the MBTA was born to service a 39 community constituency. Because the MTA fell into the red years before the official public reorganization, maintenance of track, yards, and right-of-way suffered significant neglect.

A number of forces were at work at the time which influenced the current status of track maintenance policy. These include the change in maintenance expenditure resource allocation from a budget driven by farebox revenues to one solely dependent on a 50/50 formula grant for operating and maintenance (O & M) funds. With federal funding of maintenance expenditures came the imposition of track maintenance standards. Further, because the 50 percent local share was generated from both member cities and towns and the state of Massachusetts, a Blue-Ribbon advisory board, composed of industry and citizen representatives, was formed to approve the budget. The state-run Department of Public Utilities, was charged with the job of regulating safety requirements. Under the MTA, track maintenance policy was an outgrowth of an experienced-based approach and available budget. Track was maintained at the optimal level as judged by a responsible section foreman. They developed "internalized" standards which were executed at their discretion. No written minimum track maintenance policy was followed, according to senior maintenance personnel at the "T". Further, informal "standards" which did exist were non-uniform across different transit companies. For example, the section foreman responsible for track between North Station and Friend Street on the Boston Elevation may have adopted a more intensive maintenance policy than his successor for the Metropolitan Transit Authority. This factor complicated the task of maintenance standards, as does the diverse physical characteristics of the four heavy/light rail lines.

Developing objective measures to estimate the degree of deferred Maintenance of Way (MoW) on any given business day requires diligent record-keeping over long periods of time. Because many of the older Northeastern transit properties lack a rich database, it is impossible to empirically evaluate the amount of deferred maintenance inherited by the MBTA at the time of its inception.

An interview with Mr. Tom Riley, Superintendent of Rail Engineering, revealed that records pertaining to the age, location, and type as well as placement and curvature of track at specific locations was once kept on record. But this information is "archived. and would be difficult to retrieve."

To evaluate maintenance policy over the system lifetime in Boston could be accomplished only if all the "players" were to tell their story. T.K. Dyer and his colleagues have developed a simple and accurate method of evaluating deferred maintenance levels at various US railroads. Their technique is based on evaluating the percent of deferred maintenance, measured against a standardized decision rule for each component comprising the track. Data is extrapolated from ICC-required MoW reports. Information used from these reports includes systemwide age and location of rail, tie, fastener, or ballast age. Using the ICC data, for example, Dyer developed a distribution of ties and rail-in-service by installation year systemwide. A percent of ties installed by year yields a cumulative measure of track condition. Using a decision rule where approximately half the life remains at 17 years, it is possible to compare the amount of deferred maintenance for any rail network and allocate rehabilitation capital investments accordingly.

Instituting Management Reporting and Performance Monitoring

E & M Department Management is currently engaged in the process of instituting management controls through direct and indirect means. The Performance Monitoring System and the MIS designed by Klauder Associates for the special track program are ambitious examples of attempts to introduce fiscal accountability. The scheduled Defect Incident Reporting System will introduce the first on-line track performance failure monitoring system in November, 1985. The Incident Reporting System will begin to establish a database retroactive to the date it is implemented. A decision was made not to load historical defect data, therefore, it can be reasonably ascertained that this system will not be valuable for analytical purposes until a time-series database is recorded.

Selective Maintenance Policy

The Special Track Program is an expanded spot maintenance program funded outside the domain of the annual operating budget. Its need is real; track components have outlived their useful life, in lieu of preventive maintenance intervention over the equipment lifecycle. The Program is a clear manifestation of a lack of preventive maintenance programs in the past. Spot repairs are scheduled on the basis of the worst performing track segments. Although track renewal may result in specific track locations where the most intensive repairs were made, any resemblance to programmed maintenance is merely an incidental consequence born out of a crisis response.

The author concluded that lack of intermediary maintenance intervention shortens the track component lifecycle with particular reference to rail, fasteners, the plates, insulation joints and joint bars, and ballast/drainage systems. Responsibility for this outcome is, in part, a product of the federal grant disincentive to maintain equipment using O & M funds and lack of consistent internal maintenance funds.

Programmed Maintenance Policy

Programmed track renewal programs are underway (see the Five Year Plan). However, these programs do not qualify as programmed maintenance, based on the definition stated in the Introduction to this study.

Programmed maintenance is an intermediary or intensive maintenance policy which is accomplished using use and/or time-based intervention cycles. Discussion with track line personnel reveal that the level of programmed maintenance activity has actually declined in recent (5-10) years. Data were not available to quantify this relationship. The assertion is made based on extensive discussion with track line personnel.

Production Tamping

Presently there is one production tamper in service and one on order from the manufacturer for all four transit lines at the MBTA. It is operated by the road crew during non-revenue hours. Production rates, if no equipment breakdowns are experienced range from 1600 to 3600 linear feet of track per shift. However, low equipment reliability hinders the actual productivity rate due to the complex nature of a production tamper, lack of replacement parts inventory, and high incidence of special trackwork where the production tamper is rendered useless.

Production tamping is one of the most useful preventive maintenance activities which can be deployed by management. More automated equipment of this nature should be acquired to increase the frequency of tamping activities from once per year for every track segment (current approximation) to two to three times per year. Production tamping is clearly preferable to spot tamping, done by track gangs for special trackwork. Further, it is possible to achieve economies of scale by sharing the procurement and O & M equipment costs with the Commuter Rail Division. Rapid transit and light rail lines could be tamped during the spring and fall seasons when it is most needed, and commuter rail tamping could be rotated to winter and summer months.

In addition to production tamper in operation (Tamron Corp. is manufacturing the second tamper), the "T" operates three gasoline spot (Hand) tampers procurred in 1982, three Pettibone speed swings (Gantry cranes, two of which are rail or road capable), and a variety of utility, dump, and crew cars.

Production Rail Grinding

MoW equipment is available and commonly used by mainline railroads which physically grinds and burnishes the rail head to smooth cross-level deviations and reduce accelerated rail wear. Although the rail life-cycle is shortened by programmed grinding, ride quality is improved significantly. Acquisition of this equipment is recommended to operate on a regular P.M. cycle and improve track quality.

Rail Flaw Detection

Sperry Rail Services has a contract to provide rail flaw identification on all lines a minimum of one time per line segment per year. Frequency of flaw detection is perceived as supplemental to visual trackwalker inspection cycles. Detection of those rail flaws which are hairline fractures are difficult to detect visually and cannot be perceived as a substitute for visual inspection. However, if visual inspection cycles are reduced, as is currently the case, rail flaw detection frequency should be increased to at least reduce the probability of catastrophic failure for this type of defect.

Ballast and Tunnel Cleaning

No current programs to clean ballast and tunnel walls have been initiated to date. Ballast cleaning is accomplished with high pressure steam cleaning equipment combined with special solvents spraying. The purpose of this P.M. activity, especially in tunnel areas, is to improve the drainage characteristics of RoW. Oil, grime, and dust tend to saturate tie crib areas without cleaning, causing accelerated tie deterioration and increased corrosion to spikes, anchors, and ultimately the rail itself.

A regular ballast cleaning cycle would prolong track component reliability and component life at relatively nominal cost.

Drainage System Maintenance

RoW drainage collection, filtration, and distribution systems suffer from extensive deferred maintenance over many years of inactivity. Drainage is critical to reduce collection of water along the right-of-way. Although there are some activities by the P.M. crew to remove trash along the RoW, their efforts are not concentrated on drainage system maintenance. Because this activity is labor intensive, additional line personnel should be assigned to put drainage subsystems back in sound operating order, and keep them there.

Trackwalking

Since the introduction of the Management Rights Bill, maintenance policy concerning trackwalking has changed substantially. Before reviewing these changes and their impact on track quality, a definition of Chapter 581 (Management Rights) is excerpted directly from the calendar year 1982 budget:

Definition

Chapter 581 of the Acts of 1980 was enacted by the Legislature and signed by the Governor on December 7, 1980. This Chapter is commonly known as the Management Rights Act because it provides MBTA management with the capability to operate the Authority in a manner consistent with normal management perogatives. These perogatives, which include most of the major provisions of the Act, include the following:

1. The right to direct, appoint, employ, assign and promote officers, agents and employees.

2. The right to discharge and terminate employees, subject to specific clauses which prohibit such discharge or termination on the basis of race, color, religion, sex, age, national origin, handicapping condition, marital status, political affiliation, or union activities.

3. The right to plan and determine the levels of service provided by the Authority.

4. The right to direct, supervise, control, and evaluate the Authority's departments, units, and programs; as well as the right to classify positions and establish duties and productivity standards.

5. The right to develop and determine levels of staffing and training.

6. The right to determine whether goods or services should be made, leased, contracted for, or purchased on either a temporary or permanent basis.

7. The right to assign and apportion overtime.

8. The right to hire part-time employees.

Other provisions of the Act include, but are not limited to, various items concerning the responsibilities of the Board of Directors, the sale of notes and bonds, and the change in the Authority's budget from a calendar year basis to the State fiscal year as of July 1, 1983.

Due to a union appeal of this legislation, implementation of Chapter 581 did not occur until October 22, 1981 after the Federal Appeals Court affirmed the legality of the Act's provisions.

*****

With regard to trackwalking, the following policy decision was made: "On November 28, 1981, the Authority reassigned 22 of the 44 individuals who were assigned only to track walking to preventive maintenance and other duties. The remaining 22 track walkers were assigned to cover track based on needs dictated by track reliability data (increased productivity)."

The reader is asked to turn to the pertinent description of a trackwalker's job duties and that of P.M. crews to interpret the impact of this action.

Where track segments had in all locations been walked every day, only those track segments in tunnel areas are walked daily, with surface and elevated tracks walked twice weekly (see revised trackwalker's schedule). The original and previously modified track repairman's schedule was not available to the author. However, various line personnel assisted the author in reconstructing and verifying previous walking frequently. In addition to the dramatic reduction in trackwalker's frequency cycle from daily to twice per week on indicated lines, those 22 full-time trackwalkers who were re-assigned to other duties (P.M.) have been replaced by the use of "spares" when a full-time walker is sick, injured, or non-compliant. Most recently, many "jobs" described by the track repairman's schedule are not being filled by spares, reducing the reduced inspection frequency further. When this action is ordered, the result is clear; E & M Department management is violating those minimum safety requirements mandated by State Law:

Class of track	Type of Track	Required frequency
1,2,3	Main track and sidings.	Weekly with at least 3 calendar days interval between inspections or before use, if the track is used less than once a week, or twice weekly with at least 1 calendar day interval between inspections, if the track carries passenger trains or more than 10 million gross tons of traffic during the preceding calendar year.
1,2,3	Other than main track and sidings.	Monthly with at least 20 calendar days interval between inspections.
4,5,6		Twice weekly with at least 1 calendar day interval between inspections.

MBTA tracks are class 3 and should be inspected a minimum of twice weekly. To substantiate the assertion that track had previously been walked on a daily basis, the following passage is excerpted from the MBTA Track Maintenance Standards Manual (Page 232:)

2. Frequency of Inspection - Track and Special Trackwork

   a. Each track inspection must be made in accordance with the following schedule:

      Main Track and Sidings - Required frequency is daily - seven days per week.

      Operating Yards - Required frequency is four days per week.

****

In lieu of regularly scheduled hi-railer inspection (A high-railer is a self-powered device which is rail or road capable), the trackwalking function should be stabilized at least to minimum legal safety levels. Further, to the extent that a trackwalker is involved in corrective actions on-site (see description of trackwalker's activities) cutting the inspection frequency is a short-term cost saving measure which is likely to result in substantial damage to future rail quality and expected lifetime. To the extent that trackwalkers are involved in P.M. functions minimizes major and track-related defects by fixing small defects (loose bolts, moved to tie plates, loose anchors), safety is being compromised for apparent cost-savings.

ESTABLISHING A FRAMEWORK TO ANALYZE MBTA TRACK PERFORMANCE

The purpose of this chapter is to recommend specific methods of improving current track performance monitoring, and identify critical variables to be captured in initial and secondary MIS implementation phases. The long-range goal is to develop a maintenance resource allocation model based on track component life-cycle cost histories.

The impetus for the proposed plan is based on extensive review of existing reporting capabilities, successful analytical techniques introduced during the literature review, interviews with MBTA maintenance staff, and a review of the Klauder Associates MIS plan. A final objective is to assist in the creation of consistent demand-responsive major and minor preventive maintenance cycles.

Conclusions and Specific Recommendations

The purpose of this chapter is to summarize a set of general conclusions regarding the manner in which current maintenance programs and actions are conducted. The author's comments are based on a series of interviews conducted primarily with E & M personnel including representatives of both management and labor over the past three months.

In recent years, track maintenance levels, renewal programs, and new line construction activity has accelerated rapidly. Prior to this period, botomming out during the FY 1979/1980 Fiscal collapse, the maintenance function was severely depressed. If tie and rail age records were available, it would be possible to demonstrate that track

component age was at its all-time mean peak due to substantial deferred maintenance.

The MBTA is currently engaged in a full scale battle to mitigate the service impacts from deferred maintenance. Based on an analysis of the five-year plan, current track condition, and current maintenance practices and policies, both rapid transit lines and surface lines, the Engineering and Maintenance Department has not yet established adequate track preventive maintenance levels to achieve maximum equipment life, ride quality, and freedom from speed restrictions. The department does, however, show every sign of substantially improving the quality of track system-wide.

With the addition of the planned MIS, the E & M Department can begin to develop component probable life extremely curves and survivor life curves for rail, ties, and related components to optimize equipment replacement decisions.

Data Reporting and MIS Development

MBTA Management is intimately aware of the importance of good record keeping, but historically unable to staff its operating department at the level necessary to maintain satisfactory performance data. It is highly probable that the planned November implementation date for the MIS will relieve data reporting deficiencies.

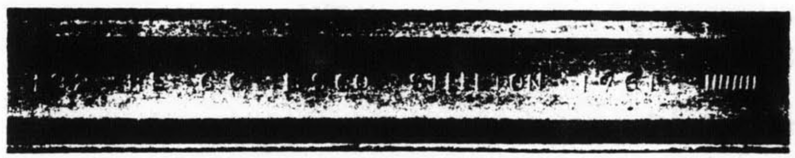
The author recommends the creation of a location specific track maintenance screen in the database. Accessed by a location identification code, the screen would provide a section for general equipment inventory. This would include the track age, weight, date of production and date of installation. Other track comments to be included are type of rail fastener, anchors, and ties in-place, number of ties per line-segment, as well as where a curve begins and ends (using engineering station markers). The description would also yield track radius by location if applicable. Secondary information would include ballast type and grade as well as cleaning frequency.

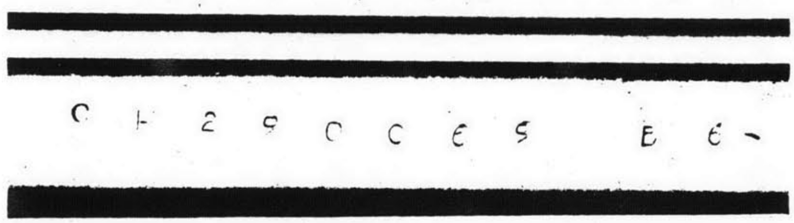
In the same screen, or a second screen, a complete track history would provide a maintenance planner with the frequency and number of major and minor preventive maintenance cycles performed by performance date. Maintenance standards would first be developed to define an exact set of maintenance actions which constitute a minor preventive maintenance cycle and a major cycle. When to perform these actions would be based either on a specific time interval, or more aptly, a specific number of vehicle trips.

Finally, an entire engineering equipment inventory is being created by Klauder Associates and E & M staff, using tag numbers for inventory control of field component identification. In the case of running rails, the section designation and heat number could be used which are rolled into the side of the rail during milling (see Exhibit 7-1) from the Sperry Rail Defect Manual) For ties, the old railroad practice of using date nails should be resurrected and expanded to include an inventory control tag number (see Exhibit 7-2).

Exhibit 7-1

Rail Section Designation and Heat Number

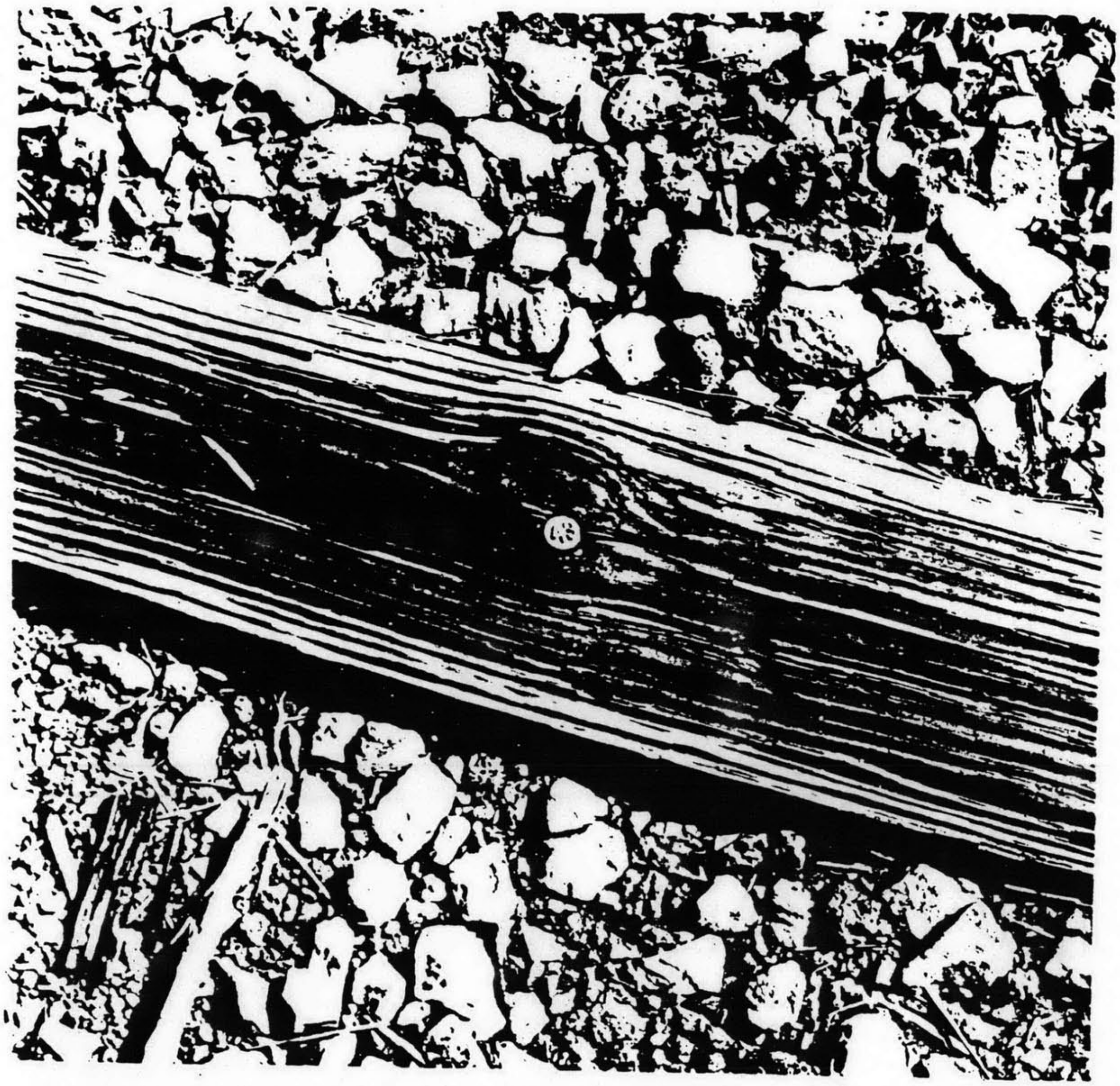




Source: Sperry Rail Defect Manual, 1964

Exhibit 7-2

TIE DATE NAIL



Source: MBTA Special Track Repair Program, 6-month Interim Report

Development of a Data-Base

Several interviews were conducted with key personnel to determine how long records have been maintained, and the availability of data necessary for the modelling process.

The purpose of this chapter is to compare the actual data with improved records to facilitate track performance measurement.

To construct a data base, the first issue concerning construction of data is to determine the smallest increment of track for which data will be aggregated. A "Best-Case" approach would subdivide each of the four MBTA rapid transit lines into track unit-miles using engineering mile-markers or unit-kilometers similar to those found on interstate highways. This strategy would enable maintenance policies' costs and benefits to be evaluated in precise and equivalent "link-segments." However, this was difficult during data-entry. The only physical markers along the track right-of-way which would have facilitated this task exist on the Arborway, Huntington Ave., and Riverside surface lines. By inspection, according to Mr. Paul Munchbank, Maintenance Control Center Coordinator, electrical power poles are spaced at approximately 100 ft. intervals along the rights-of-ways on Surface transit lines. This option was not deemed feasible because poles do not exist system-wide. Alternatively, the MBTA utilizes numbered engineering station markers. It was felt that a station-level analysis would be too rough for maintenance planning and monitoring activities. Instead, uniquely numbered signal poles were selected as nodes in the network.

With variable spacing from 20-30 feet on curved track, to upwards of 200 feet between straight sections of track, signals are natural nodes because they currently exist for all mainline trackage. Further signal poles in the study area are direction specific: with each track having its own corresponding signal pole, unlike some other transit properties and railroads who "stack" bi-directional train control lights on a single pole. The importance of this seemingly trivial fact is that two modes are used to describe a link whose specific location approximate line-haul distance, and operating direction is immediately known.

At the present time, signals are being replaced by automatic train operation (ATO) on the Red Line. The signals still physically exist however. For purposes of this study, the functional status of standing signal poles is irrelevant. Only as a physical parameter are signals important.

The E & M signal pole map could be used to identify network links, using consecutively numbered link numbers (see Exhibit 7-3).

Exhibit 7-3

E & M Signal Pole Link Map

Development and Adoption of Performance Measures

For purposes of maintenance planning repair scheduling, particularly concerning when to perform major track preventive maintenance, performance measures should be devised. These measures would facilitate instant evaluation of track condition and maintenance quality at any specific location. Because the author believes that a great deal of track deterioration is use, rather than time based, the performance measures selected should normalize track quality by vehicle-trip frequency per quarter. Hence, this suggests an on-line data base capability with the Operations Scheduling Department to determine trip-levels interactively.

Using a normal-distribution, it is possible to use the T-test for particular line links performance compared with a line or system mean. Alternatively, it may be more appropriate to re-aggregate line segments by comparable class, rail weight, or use category to identify sub-optimal track links. The smaller link distance used, the greater the accuracy in pinpointing areas of poor performance.

In addition to those systematic conclusions and suggestions presented, a series of specific recommendations follows:

1) Develop a data base to monitor track maintenance history and performance by specific surface line or rapid transit location.

2) Equip all line personnel with communications beepers capable of multiple message memory

3) Decentralize track parts repair inventory placement, along RoW-assign stocking responsibilities.

4) Implement automatic code message switching system for message center

input to output at line-level.

5) Restructure message control center reporting and repair procedures; specifically to close-out defect repair work-orders accurately, quickly, and clearly.

6) Stabilize staffing levels-trackwalking, P.M., night crew, etc.

7) Purchase and provide trackwalkers with small digital display track geometry push carts.

8) Investigate possibility of providing trackwalkers with lightweight, high-strength, epoxy-based resin or plastic double ended wrenches.

9) Develop test programs and implementation standards for running rail, ties, third-rail, insulation joints and rail joints, when using any unproven track component.

10) Develop minimum track defect standards

11) Use life-cycle costing approach to determine track major and minor P.M.'s as well as optimal change-out time, based on budget-driven grant sources.

12) Increase P.M. crews size and frequency in areas of low track reliability.

13) Define P.M. tasks and time or used-based cycle period. Test high, low, moderate P.M. cycle at different locations.

Table 7-1

STATISTICAL APPROACHES TO MGT CONTROL:
THE CASE FOR PERFORMANCE MEASUREMENT

Measure 1	=	Mean trips between track-related defects (normalized by link distance)
Measure 2	=	Mean trips between major or minor preventive maintenance cycle
Measure 3	=	Mean time between defects by defect type
Measure 4	=	Defects per vehicle-trip per period.
Measure 5	=	Ratio of track related derailments divided by all defects
Measure 6	=	Speed restrictions per vehicle-trip per location
Measure 7	=	Speed restrictions per maintenance dollar by location
Measure 8	=	Defects per maintenance dollar by location

Implementing the Data Base Design and Performance Measurement System

The previous section provided a conceptual and descriptive overview of current program monitoring and record keeping activities. It introduced a methodology to evaluate track performance and expenditure allocation. This section outlines a tailored plan to determine the effectiveness of maintenance expenditure, evaluate track performance at the component level, and facilitate when and where programmed maintenance cycles should be implemented.

Phase 1: Improving Track Condition Monitoring

In 1981, a Performance Monitoring System was established at the Engineering & Maintenance (E & M) Department. Its mission is to provide management control for all three operating divisions within E & M Building & Structures, MoW, and Signal and Power. For track performance, the author is concerned with the MoW Division Reports (Table 7-2) and the Buildings-Structures Division Report (Table 7-3). The latter division report monitors subway pump (Line 1) breakdowns per quarter. It is possible to derive a very crude measure of pump availability and reliability. Subway pumps are important because they have the capability to reduce moisture in tunnel track segments, reducing insulation joint failures and tie rot.

While these summary reports continue to be prepared manually, through

Table 7-2

ENGINEERING AND MAINTENANCE DEPARTMENT

1983 PERFORMANCE MONITORING SYSTEM STATISTICS

Month: JULY (28 Days) Quarter: 3

Division: MAINTENANCE OF WAY

Program	Month	Quarter To-Date	Quarter Goal	Same Quarter 1981	Same Quarter 1982	Preceding Quarter
1. Derailments						
A. Main Line	1	1	1	2	N.A.	3
B. Yard	3	3	1	1	N.A.	3
2. Speed Restrictions	7 (156 Days)	7 (156 Days)	9	26	N.A.	12
3. Rail Joint Failures	4	4	3	6	N.A.	13
4, Insul. Joint Failure	5	5	12	17	N.A.	18
5. Yard Switches Out-of-Service	2 (29 Days)	2 (29 Days)	7	13	N.A.	3
6. Main Line X-Overs Out-of-Service	0	0	3	8	N.A.	1

Source: MBTA

Table 7-3

ENGINEERING AND MAINTENANCE DEPARTMENT

1983 PERFORMANCE MONITORING SYSTEM STATISTICS

Month: JUNE (35 Days) Quarter: 2

Division: BUILDING-STRUCTURES

Program	Month	Quarter To-Date	Quarter Goal	Same Quarter 1981	Same Quarter 1982	Preceding Quarter
1. Subway Pump Breakdowns	3	34	55	—	—	50
2. Car & Bus Washer Breakdowns	3	20	25	—	—	45
3. Hoist Breakdowns	13	41	55	—	—	36
4. Escalator Breakdowns	49	170	—	—	—	170
5. Fare Collection Device Breakdowns:						
A. Controllers	240	518	480	—	—	508
B. "S" Boxes & Booth Passimeters	425	1040	1104	—	—	1220
C. Perey Machines	358	1182	1434	—	—	1316
6. Station Security	42	129	—	—	—	—

Source: MBTA

individual Maintenance Control Center Defect Reports, it is necessary to capture more precise reporting information. This would include the following data by program (See Appendices A-1 through A-9).

Accurate compilation of this matrix would enable monitoring of cumulative monthly failure data for selected program areas. This information could be used as the basis for a track maintenance and repair data-base for each location code. When the MIS is implemented, secondary defect data would be added to reflect all twenty-six defect codes previously identified.

Up to this point, Special Track Repair Programs and eventual monitoring of programmed maintenance activities have not been discussed. The reader is asked to refer to the Special Track Repair Program description for examples of control report contents.

A "Second Generation" Special Track Program Repair Activity Report presented in Appendix A-5 is similar to printouts now being produced. It differs in a variety of major reporting areas. On the left-hand column, activities are represented by major work element (code 1.0) and subsets of that task which may or may not be necessary for any particular task. Although the matrix provides only two broad job types--running rail replacement and rail-gauging and fitting, families of job subsets would be created and reported for all major track repair areas. The heading "% Changed Out/Unit-Mile" provides an indicator of monthly maintenance policy intensity per unit-mile of track. As components are replaced over-time, it is possible to produce cumulative age distributions of track components in specific track locations.

As the MIS system comes on-line, and as the defect incident reporting system becomes operational, data which is generated manually can be automated. Once line-personnel become trained to use the equipment, they should be encouraged to enter data directly from assigned terminal access areas;- as part of their job responsbilities. System security levels can be installed, using passwords and employee badge numbers, to insure accurate data base construction.

Phase II: Analytical Measures

The simplest analytical method for maintenance resource allocation is trend-line analysis either cross-sectionally, or over a series of observations, as the data base grows. Trend-line analysis is of value because it facilitates quick identification or componants or areas with poor performance, and can be used as an input to more sophisticated techniques.

Trend-line analysis can facilitate defect per unit-mile projections by taking an existing series of evaluations and extrapolating from them to generate statistical distributions of component defect codes over time. This would aid time or use-based programmed change-out cycles.

Output from the data base presented in the Appendices could immediately be used to generate the following performance measures:

- Defects by Type 1 through 2b, per unit-mile
  - by line, mile or system level
  - by number of vehicle-trips
  - by curve versus tangent track
  - by exposed versus underground track
  - by tie type, fastener type or rail weight
  - by month or season
- Investigate the relationship between defect type and maintenance history
  - highest % component change-outs per unit-miles should yield lowest level of failures
  - test frequency of trackwalker function with P.M. defects per unit mile
  - develop cumulative component age per unit mile

[cont.]

and test with defect level;
inverse proportional correlation expected

- Develop mean time between failures per component type

  - use Mean Time Between Failure (MTBF) to identify areas where consistently poor performance justifies renewal versus spot maintenance

  - develop defects for vehicle-trip per month for each unit-mile of track. Use to determine use-related deterioration

  - establish minimum track performance levels at unit-mile station and line level. Construct confidence intervals to monitor link performance values with that of line or system mean

  - develop family of defect and failure using elasticity measures correlators:

    - For example, a % change in trackwalker inspection frequency is correlated with an additional percentage of component-related failures

Phase III

The final stage of analytical methods recommended for a maintenance resource allocation model is to develop and implement major and minor preventive maintenance cycles. P.M. cycles would be based on the beginning year budget allocation and serve as a tool to show MBTA Advisory Board staff the positive effects in implementing such a program. Such a regular P.M. cycle could be tested against track-related derailments, speed restrictions, and defect codes to adjust intervention intervals over time.

REFERENCES

Bing, A.J. "Long-Term Maintenance-of-Way Planning Technique Development Program", Arthur D. Little, Inc., April 1983.

Bing, Alan, J. and Todd O. Burger, Robert J. Bekerian, P.D. Mattison, Debra L. Mentch, "Northeast Corridor Track Quality Analysis, October 1981-September 1983", Arthur D. Little, Inc., March 1984.

Cataldi, G. Richard and David N. Elkaim, "Track Renewal System and Wood Tie Re-use Analysis", Unified Industries, Inc., U.S. Dept. of Transportation (publ.), Washington, D.C. October 1980.

Cataldi, G. Richard and David N. Elkaim, Kenneth W. Larsen, "Track Renewal Systems: A Survey Report", Unified Industries, Inc., U.S. Dept. of Transportation (publ.), Washington, D.C. July 1979.

Fastenrath, Fritz, Railroad Track Theory and Practice, Frederick Ungar Publishing, New York, NY 1981.

Folk, Joseph, F., "Investment Analysis at Conrail", Proceedings--Eighteenth Annual Meeting ,Transportation Research Forum, (publ.), XVIII, 1, pp. 435-39, 1977.

Guenthner, Richard, P. and Kumares C. Sinha, "Maintenance, Schedule Reliability and Transit System Performance", Report Prepared for the 1982 Annual Meeting of the Transportation Research Board.

Love, John, J. "A Demand-Responsive Approach to Railroad Track Maintenance Management," MIT Master's Thesis, June 1981.

__________. "Maintenance of Track", Japanese National Railways, 1967.

__________. Maintenance Techniques for Road Surfacings: Assessment, Choice of Treatment, Planning, Implementation. Organization for Economic Cooperation and Development (OECD), (publ.), Paris, France 1978.

Markow, Michael, J. "Planning and Management Alternatives in the Rehabilitation of a National Rail System, MIT Working Paper, 1984.

__________. "MBTA Engineering and Maintenance Control Center Incident Management System-User Manual", Louis T. Klauder and Associates, April 1985.

__________. "MBTA Special Track Work Program 1984-1985 6-Month Interim Report and FY 1986 Requirements", Engineering and Maintenance Department, Internal Report, January 1985.

__________. "MBTA Track Maintenance Standards", Manual Prepared for Engineering & Maintenance Department by T.K. Dyer, Inc.

____________. "Proposed MBTA Operating Budget for FY 1983/1984", MBTA, October 1982.

____________. "1981 Current Expense Budget and Ancillary Data", MBTA, 1981.

____________. "Supplementary Current Expense Budget No. 2 Calendar Year 1980", MBTA, 1980.

Mauri, Ronald A., and Hilmy Ismail, Kim Sungwoo, David Skinner, "Railroads' Deferred Track Maintenance: Estimates Based on Safety Performance", Proceedings, Transportation Research Forum, 1980.

Mesnick, Daniel, B. and Joseph Morrisey, An Assessment of Automatic Fare Collection Equipment at Three European Transit Properties, Input-Output Computer Services, Inc., U.S. Dept. of Transportation, Transportation Systems Center, (publ.), Cambridge, MA, 1982.

Moavenzadeh, Dr. F., and M.J. Markow, B.D. Bradmeyer, Dr. M. El Hawary, Dr. M. Owais, "Overcoming Fleet Capacity Constraints in Developing Countries: Analysis of Investment and Maintenance Options", MIT Working Paper, 1982.

Nowlan, Stanley, F., and Howard F. Heap, "Reliability Centered Maintenance" Published for United Airlines, 1978.

Polenske, Karen, R., and Gerald Sussman, Richard D. Tabors, Lynn C. Todman, Adrian R. Walter, "An Assessment of Public Infrastructure in Massachusetts", Report for Joint Economic Committee by Harvard/MIT Joint Center for Urban Studies, April 1983.

Ramaswamy, Ruait. "Design of An Optimal Preventive Maintenance Program for Transit Vehicles", MIT Master's Thesis, January 1983.

Smith, Roy, T. "Track Rehabilitation and New Construction at CTA", Report prepared for 1985 Annual Meeting of the Transportation Research Board.

Sperry Rail Service. Rail Defect Manual, Itasca, CT, 1964.

Takahara, Kiyosuke. "Track Degradation Prediction for the NEC", Japanese National Railways Working Paper, July 1979.

The Track Cyclopedia. H.C. Archdeacon, (Ed.), Simmons-Boardman Publishing Corp., Omaha, NE, 1978.

Thomopoulos, Nick, T. "Preliminary Econometric Modeling for Track Maintenance Requirements", IIT Research Institute, (publ.), Chicago, IL, December 1966.

__________________. "Track Maintenance Management Information System and Training Needs Assessment", Automated Science Group, Inc., (publ.), Silver Spring, MD, April 1983.

________________. "Transit Bus Maintenance, Equipment Management, Routine Maintenance and Improving Work Zone Safety", Transportation Research Record 864, TRB and National Academy of Sciences, (publ.), Washington, D.C. 1982.

Zobrak, Marcel, J. "Track Rehabilitation and Maintenance Research Requirements", MITRE Corp., U.S. Dept. of Transportation, (publ.), Washington, D.C., January 1980. [Contains PBQ & D Approach].

INTERVIEWS

March 27, 1985 - Alan J. Bing, Arthur D. Little, Inc., Cambridge, MA.

April 22, 1985 - Thomas K. Dyer, Thomas K. Dyer, Inc., Lexington, MA.

April 22, 1985 - Andrew Sluz, Transportation Systems Center, Cambridge, MA.

APPENDIX A-1

MONTH: ______

TRACK PHYSICAL AND OPERATING CHARACTERISTICS

Unit-Mile
Location Code
Screen

LINE	COMPONENT	TAG ITEM CODE	AGE	SUPPLIER	WEIGHT	INSTALLATION DATE
	Running rail	4590234	5 years	Bethlehem Steel	100 lbs.	6/1985

APPENDIX A-2

MONTH: ____________________

TRACK ENGINEERING SCREEN

Unit-mile Location Code Screen Line	Elevated	Surface	Subway	Weighted Average Curvature (Degrees)	Weighted Average Super-elevation	Construction Date	Fastener Type	Engineering Marker Curvature Begin	Engineering Marker Curvature End	Actual Vehicle Trips per month

APPENDIX A-3

MONTH:

TRACK ENVIRONMENTAL REPORTING

Unit-Mile Location Code	% Exposed	Precipitation in inches	Ratio of Days below freezing point

APPENDIX A-4: DEFECT MONITORING AND REPORTING SYSTEM

MONTH: ____________ TABLE ____________ CAUSE ____________

Program	Track-Related	Vandalism	Human Error	Location Code	Severity Index	Total Repair Time	Total Response Time	Unit Material Cost	Unit Labor Cost	Unit Equipment Cost	**Foreman Badge Number**	**Labor Badge Nos.**	**Dept. Charged**	**Equipment Tag.No.**
1. Derailment														
A. Mainline														
B. Yard														
2. Speed Restriction														
A. Broken Rail														
B. Rail Cross-level														
C. Rail Gauge														
D. Ties Deteriorated														
3. Rail Joint Failure														
4. Insulation Joint Failure														
5. Yard Switches 005														
6. Mainline X-Overs 005														
7. Subway Pump Breakdown														
8. Broken Rail														
9. Mainline Switch 005														

APPENDIX A-5

MONTH: ______________

SPECIAL REPAIR PROGRAM ACTIVITY REPORT

Code	Activity	Number or feet installed	Location Code	% Changed out/Unit-mile	Unit Labor Cost	Unit Material Cost	Unit Equipment	Foreman Badge No.	Labor Badge No.	Dept. Charged	Contractor	Component Tag Numbers
1.0	Running rail replaced	N Feet										
1.1	Rail anchors replaced											
1.2	Spikes replaced											
1.3	Tie plates replaced											
1.4	Ties replaced											
1.5	Tamping											
1.6	Surfacing											
1.7	Lining											
2.0	Rail gauging and adjusting											
2.1	Gauge too narrow											
2.2	Gauge too wide											
2.3	Cross-level dips											
2.4	Rail surface grinding											
2.5	Shimming											

ETCETERA......

APPENDIX A-6

MONTH: ____________

PROGRAMMED MAINTENANCE PROGRAM ACTIVITY

Code	Activity	Location Code	Number or feet	% Change-out per unit-mile	Unit Labor Cost	Unit Material Cost	Unit Equipment Cost	Changed out Component Tag Numbers	Foreman Badge No.	Labor Badge No.	Repair Time
1.0	Production tamping										
2.0	Rail re-surfacing										
3.0	Insulation joint										
3.1	Inspection										
3.2	Cleaning										
3.3	End-post replacement										
4.0	Rail gauging										
5.0	Switch adjustment										
5.1	Points										
5.2	Tie Rod										
5.3	Frog										
6.0	Weed Kill										

APPENDIX A-7

MONTH: ____________

SPERRY RAIL CAR

Unit-Mile Location Code Screen	Date Inspected	Flaws Detected	Flaw Type	Severity Index	Car Number

APPENDIX A-8

MONTH: ______________________

TRACK GEOMETRY CAR

Unit-mile Location Code Screen	Date Inspected	Length of Irregularities	Lateral Deflection in inches	Longitudinal Deflection in inches	Track Quality Index	Car Number	Equipment Callibration Date	Car Number

APPENDIX A-9

MONTH: ____________________

TRACKWALKER INSPECTION

Unit-Mile Location Code	Monthly Scheduled Frequency	Monthly Actual Frequency	Weekly Schedule	Walker Badge Number(s)	% Full-Time/ % Spares	Defects code corrected on site	Materials Expended	Number/ Month	Defect Code Identified	Number per Month

Appendix B-1

CONDITIONS REQUIRING SPEED RESTRICTIONS ON REVENUE TRACK

A. GAUGE

LIGHT RAIL

1. Tangent Track and Curves greater than 1000' Center Radius
   Gauge less than 4'8 3/8", but greater than 4'8 1/8"
   Gauge greater than 4'9 1/8", but less than 4'9 3/8"
2. Curved Track less than 1000' Center Radius
   Gauge less than 4'8 1/2", but greater than 4'8 1/4"
   Gauge more than 4'9 1/8", but less than 4'9 3/8"

RAPID TRANSIT

3. Tangent Track & Curves greater than 1000' Center Radius
   Gauge less than 4'8 1/4", but greater than 4'8"
   Gauge greater than 4'9 1/4", but less than 4'9 1/2"
4. Curved Track less than 1000' Center Radius
   Gauge less than 4'8 3/8", but greater than 4'8 1/8"
   Gauge more than 4'9 1/4", but less than 4'9 1/2"

B. GEOMETRY

1. Line - deviation at middle ordinate of 62' chord, tangent and curved track, not more than 1 1/4"
2. Cross Level Deviation from zero cross level at any point on tangent or from designated elevation on curves between spirals may not be more than 1 1/4"

C. BOLTED JOINTS

1. Joint - 4 hole - more than one bolt missing
   6 hole - 2 bolts missing with no more than one from each end
2. Pull apart - up to but not more than 2" - all bolts intact
3. Joint bars - one broken (not between middle two bolts)
4. Joint bars - both cracked (not broken all the way through)

D. RAIL

1. Break - through head and base and or pulled apart up to but no more than 2" (concrete or asphalt encased rail)
2. Rail Head - broken or missing from joint area up to but no more than 2". Also, visually supervise each operation over the rail.
3. Any visible rail defect 1-1/2" or more in length
4. Wear - all rail sections with headwear and or sidewear greater than 3/4"

E. TIES AND FASTENERS

1. Joint ties - two defective or center tie defective on supported joint
2. Ties or fasteners. Three or more defective ties (or fasteners) in row provided that there is a minimum of 8 sound ties and fasteners in any 39' length of track.

F. SPECIAL WORK

1. Frog - casting or frog point worn down 5/8" and more than 6" in length
2. Switch Point - any unusual wear or chipping

G. GENERAL

This document prescribes initial minimum safety requirements for transit track that is part of the general transit system. The requirements prescribed herein apply to specific track conditions existing in isolation. Therefore, a combination of track conditions, none of which individually amounts to a deviation from the requirements herein may require remedial action to provide for safe operations over that track.

Appendix B-2

CONDITIONS REQUIRING IMMEDIATE CORRECTIVE ACTION ON REVENUE TRACK

A. GAUGE

LIGHT RAIL

1. Tangent Track and Curves greater than 1,000' Center Radius

   Gauge 4'8 1/8" or less
   Gauge 4'9 3/8" or greater

2. Curved Track less than 1,000' Center Radius

   Gauge 4'8 1/4" or less
   Gauge 4'9 3/8" or greater

RAPID TRANSIT LINES

3. Tangent Track and Curves greater than 1,000' Center Radius

   Gauge 4'8" or less
   Gauge 4'9 1/2" or greater

4. Curved Track less than 1,000' Center Radius

   Gauge 4'8 1/8" or less
   Gauge 4'9 1/2" or greater

B. GEOMETRY

1. Line - deviation at middle ordinate of 62' chord, tangent and curved track, more than 1 1/4"
2. Cross Level Deviation - from zero cross level at any point on tangent or from designated elevation on curves between spirals, more than 1 1/4"

C. BOLTED JOINTS

1. Joint - 4 hole - more than 1 bolt missing from either end of the joint

   Joint - 6 hole - 2 bolts or more missing from either end

   Pull Apart - Over 2", all bolts intact

   Joint Bars - both broken or one broken and one cracked or one broken between middle two bolt holes

D. RAIL

1. Break - through head and base and or pulled apart more than 2" (concrete or asphalt encased rail)
2. Rail Head - broken or missing from joint area greater than 2"
3. Any visible rail defect 1 1/2" or more.

E. TIES AND FASTENERS

Ties and Fasteners - more than 4 defective ties or fasteners in a row or less than 8 sound ties and fasteners in any 39' length of track

F. SPECIAL WORK

1. Frogs - casting or frog point worn down 5/8" and more than 6" in length
2. Switch Points - any severe unusual wear or chipping
3. Switch Points - any opening
4. Guard check Gauge at Frogs -

   Rapid Transit - when less than 4'6 3/8"
   Light Rail - when less than 4'7"

FRA TRACK SAFETY STANDARDS

SUBPART A - GENERAL

‡ 213.1 Scope of part.

This part prescribes initial minimum safety requirements for railroad track that is part of the general railroad system of transportation. The requirements prescribed in this part apply to specific track conditions existing in isolation. Therefore, a combination of track conditions, none of which individually amounts to a deviation from the requirements in this part, may require remedial action to provide for safe operations over that track.

‡ 213.3 Application.

(a) Except as provided in paragraphs (b) and (c) of this section, this part applies to all standard gage track in the general railroad system of transportation.

(b) This part does not apply to track-

(1) Located inside an installation which is not part of the general railroad system of transportation; or

(2) Used exclusively for rapid transit, commuter, or other short-haul passenger service in a metropolitan or suburban area.

(c) Until October 6, 1972, Subparts A, B, D (except ‡ 213.109), E, and F of this part do not apply to track constructed or under construction before October 15, 1971. Until October 16, 1973, Subpart C and ‡ 213.109 of Subpart D do not apply to track constructed or under construction before October 15, 1971.

‡213.5 Responsibility of track owners.

(a) Any owner of track to which this part applies who knows or has notice that the track does not comply with the requirements of this part, shall-

(1) Bring the track into compliance; or

(2) Halt operations over that track.

(b) If an owner of track to which this part applies assigns responsibility for the track to another person (by lease or otherwise), any party to that assignment may petition the Federal Railroad Administrator to recognize the person to whom that responsibility is assigned for purposes of compliance with this part. Each petition must be in writing and include the following-

(1) The name and address of the track owner;

(2) The name and address of the person to whom responsibility is assigned (assignee);

(3) A statement of the exact relationship between the track owner and the assignee;

(4) A precise identification of the track;

(5) A statement as to the competence and ability of the assignee to carry out the duties of the track owner under this part; and

(6) A statement signed by the assignee acknowledging the assignment of responsibility for purpose of compliance with this part.

(c) If the Administrator is satisfied that the assignee is competent and able to carry out the duties and responsibilities of the track owner under this part, he may grant the petition subject to any conditions he deems necessary. If the Administrator grants a petition under this section, he shall so notify the owner and assignee. After the Administrator grants a petition, he may hold the track owner or the assignee both responsible for compliance with the part and subject to penalties under ‡ 213.15.

‡213.7 Designation of qualified persons to supervise certain renewals and inspect track.

(a) Each track owner to which this part applies shall designate qualified persons to supervise restorations and renewals of track under traffic conditions. Each person designated must have-

(1) At least-

(i) 1 year of supervisory experience in railroad track maintenance; or

(ii) A combination of supervisory experience in track maintenance and training from a course in track maintenance or from a college level educational program related to track maintenance;

(2) Demonstrated to the owner that he-

(i) Knows and understands the requirements of this part;

(ii) Can detect deviations from those requirements; and

(iii) Can prescribe appropriate remedial action to correct or safely compensate for those deviations; and

(3) Written authorization from the track owner to prescribe remedial actions to correct or safely compensate for deviations from the requirements in this part.

(b) Each track owner to which this part applies shall designate qualified persons to inspect track for defects. Each person designated must have-

(1) At least-

(i) 1 year of experience in railroad track inspection; or

(ii) A combination of experience in track inspection and training from a course in track inspection or from a college level educational program related to track inspection;

(2) Demonstrated to the owner that he-

(i) Knows and understands the requirements of this part;

(ii) Can detect deviations from those requirements; and

(iii) Can prescribe appropriate remedial action to correct or safely compensate for those deviations; and

(3) Written authorization from the track owner to prescribe remedial actions to correct or safely compensate for deviations from the requirements of this part, pending review by a qualified person designated under paragraph (a) of this section.

(c) With respect to designations under paragraphs (a) and (b) of this section, each track owner must maintain written records of-

(1) Each designation in effect;

(2) The basis for each designation; and

(3) Track inspections made by each designated person as required by ‡ 213.241.

These records must be kept available for inspection or copying by the Federal Railroad Adminstrator during regular business hours.

FRA TRACK SAFETY STANDARDS

‡ 213.9 Classes of track: operating speed limits.

(a) Except as provided in paragraphs (b) and (c) of this section and ‡‡ 213.57(b), 213.59(a), 213.105, 213.113(a) and (b), and 213.137(b) and (c), the following maximum allowable operating speeds apply:

Over track that meets all of the requirements prescribed in this part for-	The maximum allowable operating speed for freight trains is-	The maximum allowable operating speed for passenger trains is-
Class 1 track	10 m.p.h.	15 m.p.h.
Class 2 track	25 m.p.h.	30 m.p.h.
Class 3 track	40 m.p.h.	60 m.p.h.
Class 4 track	60 m.p.h.	80 m.p.h.
Class 5 track	80 m.p.h.	90 m.p.h.
Class 6 track	110 m.p.h.	110 m.p.h.

(b) If a segment of track does not meet all of the requirements for its intended class, it is reclassified to the next lowest class of track for which it does meet all of the requirements of this part. However, if it does not at least meet the requirements for class 1 track, no operations may be conducted over that segment except as provided in ‡ 213.11.

(C) Maximum operating speed may not exceed 110 m.p.h. without prior approval of the Federal Railroad Administrator. Petitions for approval must be filed in the manner and contain the information required by ‡ 211.11 of this chapter. Each petition must provide sufficient information concerning the perfomance characteristics of the track, signaling, grade crossing protection, trespasser control where appropriate, and equipment involved and also concerning maintenance and inspection practices and procedures to be followed, to establish that the proposed speed can be sustained in safety.

‡ 213.11 Restoration or renewal of track under traffic conditions.

If, during a period of restoration or renewal, track is under traffic conditions and does not meet all of the requirements prescribed in this part, the work and operations on the track must be under the continuous supervision of a person designated under ‡ 213.7(a).

‡ 213.13 Measuring track not under load.

When unloaded track is measured to determine compliance with requirements of this part, the amount of rail movement, if any, that occurs while the track is loaded must be added to the measurements of the unloaded track.

‡ 213.15 Civil penalty.

(a) Any owner of track to which this part applies, or any person held by the Federal Railroad Administrator to be responsible under ‡ 213.5(c), who violates any requirement prescribed in this part is subject to a civil penalty of at least $250 but not more than $2,500.

(b) For the purpose of this section, each day a violation persists shall be treated as a separate offense.

‡ 213.17 Exemptions.

(a) Any owner of track to which this part applies may petition the Federal Railroad Administrator for exemption from any or all requirements prescribed in this part.

(b) Each petition for exemption under this section must be filed in the manner and contain the information required by ‡ 211.11 of this chapter.

(c) If the Administrator finds that an exemption is in the public interest and is consistent with the railroad safety, he may grant the exemption subject to any conditions he deems necessary. Notice of each exemption granted is published in the Federal Register together with a statement of the reasons therefor.

SUBPART B - ROADBED

‡ 213.31 Scope.

This subpart prescribes the minimum requirements for roadbed and areas immediately adjacent to roadbed.

‡ 213.33 Drainage.

Each drainage or other water carrying facility under or immediately adjacent to the roadbed must be maintained and kept free of obstruction, to accommodate expected water flow for the area concerned.

‡ 213.37 Vegetation.

Vegetation on railroad property which is on or immediately adjacent to roadbed must be controlled so that it does not-

(a) Become a fire hazard to track-carrying structures;

(b) Obstruct visibility of railroad signs and signals;

(c) Interfere with railroad employees performing normal trackside duties;

(d) Prevent proper functioning of signal and communication lines; or

(e) Prevent railroad employees from visually inspecting moving equipment from their normal duty stations.

SUBPART C - TRACK GEOMETRY

‡213.51 Scope.

This subpart prescribes requirements for the gage, alinement, and surface of track, and the elevation of outer rails and speed limitations for curved track.

‡ 213.52 Gage.

Gage is measured between the heads of the rails at right angles to the rails in a plane five-eighths of an inch below the top of the rail head.

(b) Gage must be within the limits prescribed in the following table:

Class of track	The gage of tangent track must be -		The gage of curved track must be -	
	At least -	But not more than -	At least -	But not more than -
1	4'8"	4'9 3/4"	4'8"	4'9 3/4"
2 and 3	4'8"	4'9 1/2"	4'8"	4'9 3/4"
4	4'8"	4'9 1/4"	4'8"	4'9 1/2"
5	4'8"	4'9"	4'8"	4'9 1/2"
6	4'8"	4'8 3/4"	4'8"	4'9"

‡ 213.55 Alinement.

Alinement may not deviate from uniformity more than the amount prescribed in the following table:

FRA TRACK SAFETY STANDARDS

Class of track	Tangent track The deviation of the mid-offset from 62-foot line[1] may not be more than-	Curved track The deviation of the mid-ordinate from 62-foot chord[2] may not be more than-
1	5"	5"
2	3"	3"
3	1 3/4"	1 3/4"
4	1 1/2"	1 1/2"
5	3/4"	5/8"
6	1/2"	3/8"

[1]The ends of the line must be at points on the gage side of the line rail, five-eighths of an inch below the top of the railhead. Either rail may be used as the line rail, however, the same rail must be used for the full length of that tangential segment of track.

[2]The ends of the chord must be at points on the gage side of the outer rail, five-eighths of an inch below the top of the railhead.

‡ 213.57 Curves; elevation and speed limitations.

(a) Except as provided in ‡ 213.63, the outside rail of a curve may not be lower than the inside rail or have more than 6 inches of elevation.

(b) The maximum allowable operating speed for each curve is determined by the following formula:

$$V\ max = \sqrt{\frac{Ea + 3}{0.0007D}}$$

where

V max = Maximum allowable operating speed (miles per hour).

E a = Actual elevation of outside rail (inches).

D = Degree of curvature (degrees).

Appendix A is a table of maximum allowable operating speed computed in accordance with this formula for various elevations and degrees of curvature.

‡ 213.59 Elevation of curved track; runoff.

(a) If a curve is elevated, the full elevation must be provided throughout the curve, unless physical conditions do not permit. If elevation runoff occurs in a curve, the actual minimum elevation must be used in computing the maximum allowable operating speed for that curve under ‡ 213.57(b).

(b) Elevation runoff must be at a uniform rate, within the limits of track surface deviation prescribed in ‡ 213.63, and it must extend at least the ful length of the spirals. If physical conditions do not permit a spiral long enough to accommodate the minimum length of runoff, part of the runoff may be on tangent track.

‡ 213.61 Curve data for classes 4 through 6 track.

(a) Each owner of track to which this part applies shall maintain a record of each curve in its classes 4 through 6 track. The record must contain the following information:

(1) Location;

(2) Degree of curvature;

(3) Designated elevation;

(4) Designated length of elevation runoff; and

(5) Maximum allowable operating speed.

‡ 213.63 Track surface.

Each owner of track to which this part applies shall maintain the surface of its track within the limits prescribed in the following table:

Track surface	Class of track 1	2	3	4	5	6
The runoff in any 31 feet of rail at the end of a raise may not be more than........	3 1/2"	3"	2"	1 1/2"	1"	1/2"
The deviation from uniform profile on either rail at the midordinate of a 62-foot chord may not be more than...	3"	2 3/4"	2 1/4"	2"	1 1/4"	1/2"
Deviation from designated elevation on spirals may not be more than........	1 3/4"	1 1/2"	1 1/4"	1"	3/4"	1/2"
Variation in cross level on spirals in any 31 feet may not be more than........	2"	1 3/4"	1 1/4"	1"	3/4"	1/2"
Deviation from zero cross level at any point on tangent or from designated elevation on curves between spirals may not be more than...	3"	2"	1 3/4"	1 1/4"	1"	1/2"
The difference in cross level between any two points less than 62 feet apart on tangents and curves between sprirals may not be more than...	3"	2"	1 3/4"	1 1/4"	1"	5/8"

SUBPART D - TRACK STRUCTURE

‡ 213.101 Scope.

This subpart prescribes minimum requirements for ballast, crossties, track assembly fittings, and the physical condition of rails.

‡ 213.103 Ballast; general

Unless it it otherwise structurally supported, all track must be supported by material which will-

(a) Transmit and distribute the load of the track and railroad rolling equipment to the subgrade;

(b) Restrain the track laterally, longitudinally, and vertically under dynamic loads imposed by railroad rolling equipment and thermal stress exerted by the rails;

FRA TRACK SAFETY STANDARDS

(c) Provide adequate drainage for the track; and

(d) Maintain proper track cross-level, surface, and alinement.

‡ 213.105 Ballast; disturbed track.

If a track is disturbed, a person designated under ‡ 213.7 shall examine the track to determine whether or not the ballast is sufficiently compacted to perform the functions designated in ‡ 213.103. If the person making the examination considers it to be necessary in the interest of safety, operating speed over the disturbed segment of track must be reduced to a speed he considers safe.

‡ 213.109 Crossties.

(a) Crossties may be made of any material to which rails can be securely fastened. The material must be capable of holding the rails to gage within the limits prescribed in ‡ 213.53(b) and distributing the load from the rails to the ballast section.

(b) A timber crosstie is considered to be defective when it is-

(1) Broken through;

(2) Split or otherwise impaired to the extent it will not hold spikes or will allow the ballast to work through;

(3) So deteriorated that the tie plate or base of rail can move laterally more than one-half inch relative to the crosstie;

(4) Cut by the tie plate through more than 40 percent of its thickness; or

(5) Not spiked as required by ‡ 213.127.

(c) If timber crossties are used, each 39 feet of track must be supported by non-defective ties as set forth in the following table:

Class of track	Minimum number of nondefective ties per 39 ft. of track	Maximum distance between non-defective ties (center to center)
1	5	100"
2,3	8	70"
4,5	12	48"
6	14	48"

(d) If timber ties are used, the minimum number of non-defective ties under a rail joint and their relative positions under the joint are described in the following chart. The letters in the chart correspond to letter underneath the ties for each type of joint depicted.

Insert page 15

Class of track	Minimum number of non-defective ties under a joint	Required position of non-defective ties	
		Supported Joint	Suspended Joint
1	One	X, Y, or Z	X or Y
2, 3	One	Y	X or Y
4, 5, 6	Two	X and Y or Y and Z	X and Y

(e) Except in an emergency or for a temporary installation of not more than six months duration, crossties may not be interlaced to take the place of switch ties.

‡ 213.113 Defective rails.

(a) When an owner of track to which this part applies learns, through inspection or otherwise, that a rail in that rack contains any of the defects listed in the following table, a person designated under ‡ 213.7 shall determine whether or not the track may continue in use. If he determines that the track may continue in use, operation over the defective rail is not permitted until-

(1) The rail is replaced; or

(2) The remedial action prescribed in the table is initiated:

Remedial Action

Note:

A - Assign person designated under ‡ 213.7 to visually supervise each operation over defective rail.

B - Limit operating speed to 10 m.p.h. over defective rail.

C - Apply joint bars bolted only through the outermost holes to defect within 20 days after it is determined to continue the track in use. In the case of classes 3 through 6 track, limit operating speed over defective rail to 30 m.p.h. until angle bars are applied; thereafter, limit speed to 50 m.p.h. or the maximum allowable speed under ‡ 213.9 for the class of track concerned, which ever is lower.

D - Apply joint bars bolted only through the outermost holes to defect within 10 days after it is determined to continue the track in use. Limit operating speed over defective rail to 10 m.p.h. until angle bars are applied; thereafter, limit speed to 50 m.p.h. or the maximum allowable speed under ‡ 213.9 for the class of track concerned, which ever is lower.

E - Apply joint bars to defect and bolt in accordance with ‡ 213.121 (d) and (e).

F - Inspect rail ninety days after it is determined to continue the track in use.

G - Inspect rail thirty days after it is determined to continue the track in use.

H - Limit operating speed over defective rail to 50 m.p.h. or the maximum allowable speed under ‡ 213.9 for the class of track concerned, which ever is lower.

I - Limit operating speed over defective rail to 30 m.p.h. or the maximum allowable speed under ‡ 213.9 for the class of track concerned, which ever is lower.

(b) If a rail in classes 3 through 6 track or class 2 track on which passenger trains operate evidences any of the conditions listed in the following table, the remedial action prescribed in the table must be taken:

FRA TRACK SAFETY STANDARDS

Defect	Length of defect (inch) More than	Length of defect (inch) But not more than	Percent of rail head cross-sectional area weakened by defect Less than	Percent of rail head cross-sectional area weakened by defect But not less than	If defective rail is not replaced, take the remedial action prescribed in note
Transverse fissure			20		B.
			100	20	B.
				100	A.
Compound fissure			20		B.
			100	20	B.
				100	A.
Detail fracture Engine burn fracture Defective weld			20		C.
			100	20	D.
				100	A, or E and H.

Defect	Length of defect (inch) More than	Length of defect (inch) But not more than	If defective rail is not replaced, take the remedial action prescribed in note
Horizontal split head Vertical split head	0	2	H and F.
	2	4	I and G.
	4		B.
	(Break out in rail head)		A.
Split web Piped rail Head web separation	0	1/2	H and F.
	1/2	3	I and G.
	3		B.
	(Break out in railhead)		A.
Bolt hole crack	0	1/2	H and F.
	1/2	1 1/2	I and G.
	1 1/2		B.
	(Break out in railhead)		A.
Broken base	0	6	E and I.
	6		(Replace rail).
Ordinary break			A or E.
Damaged rail			C.

FRA TRACK SAFETY STANDARDS

Condition	Remedial Action: If a person designated under ‡ 213.7 determines that condition requires rail be replaced	Remedial Action: If a person designated under ‡ 213.7 determines that condition does not require rail be replaced
Shelly spots Head checks. Engine burn (but not fracture).	Limit speed to 20 m.p.h. and schedule the rail for replacement	Inspect the rail for internal defects at intervals of not more than every 12 months.
Mill defect. Flaking..... Slivered..... Corrugated. Corroded...	.....do.....	Inspect the rail at intervals of not more than every 6 months

(c) As used in this section-

(1) "Transverse Fissure" means a progressive crosswise fracture starting from a crystalline center or nucleus inside the head from which it spreads outward as a smooth, bright, or dark, round or oval surface substantially at a right angle to the length of the rail. The distinguishing features of a transverse fissure from other types of fractures or defects are the crystalline center or nucleus and the nearly smooth surface of the development which surrounds it.

(2) "Compound Fissure" means a progressive fracture originating in a horizontal split head which turns up or down in the head of the rail as a smooth, bright, or dark surface progressing until substantially at a right angle to the length of the rail. Compound fissures require examination of both faces of the fracture to locate the horizontal split head from which they originate.

(3) "Horizontal Split Head" means a horizontal progressive defect originating inside of the rail head, usually one-quarter inch or more below the running surface and progressing horizontally in all directions, and generally accompanied by a flat spot on the running surface. The defect appears as a crack lengthwise of the rail when it reaches the sides of the rail head.

(4) "Vertical Split Head" means a vertical split through or near the middle of the head, and extending into or through it. A crack or rust streak may show under the head close to the web or pieces may be split off the side of the head.

(5) "Split Web" means a lengthwise crack along the side of the web and extending into or through it.

(6) "Piped Rail" means a vertical split in a rail, usually in the web, due to a failure of the sides of the shrinkage cavity in the ingot to unite in rolling.

(7) "Broken Base" means any break in the base of a rail.

(8) "Detail Fracture" means a progressive fracture originating at or near the surface of the rail head. These fractures should not be confused with transverse fissures, compound fissures, or other defects which have internal origins. Detail fractures may arise from shelly spots, head checks, or flaking.

(9) "Engine Burn Fracture" means a progressive fracture originating in spots where driving wheels have slipped on top of the rail head. In developing downward they frequently resemble the compound or even transverse fissure with which they should not be confused or classified.

(10) "Ordinary Break" means a partial or complete break in which there is no sign of a fissure, and in which none of the other defects described in this paragraph are found.

(11) "Damaged Rail" means any rail broken or injured by wrecks, broken, flat, or unbalanced wheels, slipping, or similar causes.

(12) "Shelly Spots" means a condition where a thin (usually three-eighths inch in depth or less) shell-like piece of surface metal becomes separated from the parent metal in the railhead, generally at the gage corner. It may be evidenced by a black spot appearing on the railhead over the zone of separation or a piece of metal breaking out completely, leaving a shallow cavity in the railhead. In the case of a small shell there may be no surface evidence, the existence of the shell being apparent only after the rail is broken or sectioned.

(13) "Head Checks" means hairline cracks which appear in the gage corner of the rail head, at any angle with the length of the rail. When not readily visible the presence of the check may often be detected by the raspy feeling of their sharp edges.

(14) "Flaking" means small shallow flakes of surface metal generally not more than one-quarter inch in length or width break out of the gage corner of the railhead.

‡ 213.115 Rail end mismatch.

Any mismatch of rails by joints may not be more than that prescribed by the following table:

Class of track	Any mismatch of rails at joint may not be more than the following: On the tread of the rail ends (inch)	On the gage side of the rail ends (inch)
1	1/4	1/4
2	1/4	3/16
3	3/16	3/16
4,5	1/8	1/8
6	1/8	1/8

‡ 213.117 Rail end batter.

(a) Rail end batter is the depth of depression at one-half inch from the rail end. It is measured by placing an 18-inch straightedge on the tread on the rail end, without bridging the joint, and measuring the distance between the bottom of the straightedge and the top of the rail at one-half inch from the rail end.

(b) Rail end batter may not be more than that prescribed by the following table:

Class of track	Rail end batter may not be more than - (inch)
1	1/2
2	3/8
3	3/8
4	1/4
5	1/8
6	1/8

FRA TRACK SAFETY STANDARDS

‡ 213.119 Continuous welded rail.

(a) When continuous welded rail is being installed, it must be installed at, or adjusted for, a rail temperature range that should not result in compressive or tensile forces that will produce lateral displacement of the track or pulling apart of rail ends or welds.

(b) After continuous welded rail has been installed it should not be disturbed at rail temperatures higher than its installation or adjusted installation temperature.

‡ 213.121 Rail joints.

(a) Each rail joint, insulated joint, and compromise joint must be of the proper design and dimensions for the rail on which it is applied.

(b) If a joint bar on classes 3 through 6 track is cracked, broken, or because of wear allows vertical movement of either rail when all bolts are tight, it must be replaced.

(c) If a joint bar is cracked or broken between the middle two bolt holes it must be replaced.

(d) In the case of conventional jointed track, each rail must be bolted with at least two bolts at each joint in classes 2 through 6 track, and with at least one bolt in class 1 track.

(e) In the case of continuous welded rail track, each rail must be bolted with at least two bolts at each joint.

(f) Each joint bar must be held in position by track bolts tightened to allow the joint bar to firmly support the abutting rail ends and to allow longitudinal movement of the rail in the joint to accommodate expansion and contraction due to temperature variations. When out-of-face, no-slip, joint-to-rail contact exists by design, the requirements of this paragraph do not apply. Those locations are considered to be continuous welded rail track and must meet all the requirements for continuous welded rail track prescribed in this part.

(g) No rail or angle bars having a torch cut or burned bolt hole may be used in classes 3 through 6 track.

‡ 213.123 Tie plates.

(a) In classes 3 through 6 track where timber crossties are in use there must be tie plates under the running rails on at least eight of any 10 consecutive ties.

(b) Tie plates having shoulders must be placed so that no part of the shoulder is under the base of the rail.

‡ 213.125 Rail anchoring.

Longitudinal rail movement must be effectively controlled. If rail anchors which bear on the sides of ties are used for this purpose, they must be on the same side of the tie on both rails.

‡ 213.127 Track spikes.

(a) When conventional track is used with timber ties and cut track spikes, the rails must be spiked to the ties with at least one line-holding spike on the gage side and one line-holding spike on the field side. The total number of track spikes per rail per tie, including plate-holding spikes, must be at least the number prescribed in the following table:

Minimum number of track spikes per rail per tie, including plate-holding spikes.

Class of track	Tangent track and curved track with not more than 2° of curvature	Curved track with more than 2° but not more than 4° of curvature	Curved track with more than 4° but not more than 6° of curvature	Curved track with more than 6° of curvature
1	2	2	2	2
2	2	2	2	3
3	2	2	2	3
4	2	2	3	-
5	2	3	-	-
6	2	-	-	-

(b) A tie that does not meet the requirements of paragraph (a) of this section is considered to be defective for purposes of ‡ 213.109(b).

‡ 213.129 Track shims.

(a) If track does not meet the geometric standards in Subpart C of this part and working of ballast is not possible due to weather or other natural conditions, track shims may be installed to correct the deficiencies. If shims are used, they must be removed and the track resurfaced as soon as weather and other natual conditions permit.

(b) When shims are used they must be-

(1) At least the size of the tie plate;

(2) Inserted directly on top of the tie, beneath the rail and tie plate;

(3) Spiked directly to the tie with spikes which penetrate the tie at least 4 inches.

(c) When a rail is shimmed more than 1 1/2 inches, it must be securely braced on at least every third tie for the full length of the shimming.

(d) When a rail is shimmed more than 2 inches a combination of shims and 2-inch or 4-inch planks, as the case may be, must be used with the shims on top of the planks.

‡ 213.131 Planks used in shimmings.

(a) Planks used in shimming must be at least as wide as the tie plates, but in no case less than 5 1/2 inches wide. Whenever possible they must extend the full length of the tie. If a plank is shorter than the tie, it must be at least 3 feet long and its outer end must be flush with the end of the tie.

(b) When planks are used in shimming on uneven ties, or if the two rails being shimmed heave unevenly, additional shims may be placed between the ties and planks under the rails to compensate for the unevenness.

(c) Plans must be nailed to the ties with at least four 8-inch wire spikes. Before spiking the rails or shim braces, planks must be bored with 5/8-inch holes.

‡ 213.133 Turnouts and track crossings generally.

(a) In turnouts and track crossings, the fastenings must be intact and maintained so as to keep the components securely in place. Also, each switch, frog, and guard rail must be kept free of obstructions that may interfere with the passage of wheels.

(b) Classes 4 through 6 track must be equipped with rail anchors through and on each side of track crossings and turnouts, to restrain rail movements affecting the position of switch points and frogs.

FRA TRACK SAFETY STANDARDS

(c) Each flangeway at turnouts and track crossings must be at least 1 1/2 inches wide.

‡ 213.135 Switches.

(a) Each stock rail must be securely seated in switch plates, but care must be used to avoid canting the rail by overtightening the rail braces.

(b) Each switch point must fit its stock rail properly, with the switch stand in either of its closed positions to allow wheels to pass the switch point. Lateral and vertical movement of a stock rail in the switch plates or of a switch plate on a tie must not adversely affect the fit of the switch point to the stock rail.

(c) Each switch must be maintained so that the outer edge of the wheel tread cannot contact the gage side of the stock rail.

(d) The heel of each switch rail must be secure and the bolts in each heel must be kept tight.

(e) Each switch stand and connecting rod must be securely fastened and operable without excessive lost motion.

(f) Each throw lever must be maintained so that it cannot be operated with the lock or keeper in place.

(g) Each switch position indicator must be clearly visible at all times.

(h) Unusually chipped or worn switch points must be repaired or replaced. Metal flow must be removed to insure proper closure.

‡ 213.137 Frogs.

(a) The flangeway depth measured from a plane across the wheel-bearing area of a frog on class 1 track may not be less than 1 3/8 inches, or less than 1 1/2 inches on classes 2 through 6 track.

(b) If a frog point is chipped, broken, or worn more than five eighths inch down and 6 inches back, operating speed over that frog may not be more than 10 miles per hour.

(c) If the tread portion of a frog casting is worn down more than three-eighths inch below the original contour, operating speed over that frog may not be more than 10 miles per hour.

‡ 213.139 Spring rail frogs.

(a) The outer edge of a wheel tread may not contact the gage side of a spring wing rail.

(b) The toe of each wing rail must be solidly tamped and fully and tightly bolted.

(c) Each frog with a bolt hole defect or head-web separation must be replaced.

(d) Each spring must have a tension sufficient to hold the wing rail against the point rail.

(e) The clearance between the holddown housing and the horn may not be more than one-fourth of an inch.

‡ 213.141 Self-guarded frogs.

(a) The raised guard on a self-guarded frog may not be worn more than three-eighths of an inch.

(b) If repairs are made to a self-guarded frog without removing it from service, the guarding face must be restored before rebuilding the point.

‡ 213.143 Frog guard rails and guard faces; gage.

The guard check and guard face gages in frogs must be within the limits prescribed in the following table:

Class of track	**Guard check gage** The distance between the gage line of a frog to the guard line[1] of its guard rail or guarding face, measured across the track at right angles to the gage line,[2] may not be less than-	**Guard face gage** The distance between guard lines,[1] measured across the track at right angles to the gage line,[2] may not be more than-
1	4' 6 1/8"	4' 5 1/4"
2	4' 6 1/4"	4' 5 1/8"
3,4	4' 6 3/8"	4' 5 1/8"
5,6	4' 6 1/2"	4' 5"

[1]A line along that side of the flangeway which is nearer to the center of the track and at the same elevation as the gage line.

[2]A line 5/8 inch below the top of the center line of the head of the running rail, or corresponding location of the tread portion of the track structure.

SUBPART E - TRACK APPLIANCES and TRACK - RELATED DEVICES

‡ 213.201 Scope.

This subpart prescribes minimum requirements for certain track appliances and track-related devices.

‡ 213.205 Derails.

(a) Each derail must be clearly visible. When in a locked position a derail must be free of any lost motion which would allow it to be operated without removing the lock.

(b) When the lever of a remotely controlled derail is operated and latched it must actuate the derail.

‡ 213.207 Switch heaters.

The operation of a switch heater must not interfere with the proper operation of the switch or otherwise jeopardize the safety of railroad equipment.

SUBPART F - INSPECTION

‡ 213.231 Scope.

This subpart prescribes requirements for the frequency and manner of inspecting track to detect deviations from the standards prescribed in this part.

‡ 213.233 Track inspections.

(a) All track must be inspected in accordance with the schedule prescribed in paragraph (c) of this section by a person designated under ‡ 213.7.

(b) Each inspection must be made on foot or by riding over the track in a vehicle at a speed that allows the person making the inspection to visually inspect the track structure for compliance with this part. However, mechanical or electrical inspection devices may be used to supplement visual inspection. If a vehicle is used for visual inspection, the speed of the vehicle may not be more than 5 miles per hour when passing over track crossings, highway crossings, or switches.

(c) Each track inspection must be made in accordance with the following schedule:

Appendix C-1

FRA TRACK SAFETY STANDARDS

Degree of Curvature	Elevation of outer rail (inches): 0	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6
	Maximum allowable operating speed (mph)												
0°30'	93	100	107										
0°40'	80	87	93	98	103	109							
0°50'	72	78	83	88	93	97	101	106	110				
1°00'	66	71	76	80	85	89	93	96	100	104	107	110	
1°15'	59	63	68	72	76	79	83	86	89	93	96	99	101
1°30'	54	58	62	66	69	72	76	79	82	85	87	90	93
1°45'	50	54	57	61	64	67	70	73	76	78	81	83	86
2°00'	46	50	54	57	60	63	66	68	71	73	76	78	80
2°15'	44	47	50	54	56	59	62	64	67	69	71	74	76
2°30'	41	45	48	51	54	56	59	61	63	66	68	70	72
2°45'	40	43	46	48	51	54	56	58	60	62	65	66	68
3°00'	38	41	44	46	49	51	54	56	58	60	62	64	66
3°15'	36	39	42	45	47	49	51	54	56	57	59	61	63
3°30'	35	38	40	43	45	47	50	52	54	55	57	59	61
3°45'	34	37	39	41	44	46	48	50	52	54	55	57	59
4°00'	33	35	38	40	42	44	46	48	50	52	54	55	57
4°30'	31	33	36	38	40	42	44	45	47	49	50	52	54
5°00'	29	32	34	36	38	40	41	43	45	46	48	49	51
5°30'	28	30	32	34	36	38	40	41	43	44	46	47	48
6°00'	27	29	31	33	35	36	38	39	41	42	44	45	46
6°30'	26	28	30	31	33	35	36	38	39	41	42	43	45
7°00'	25	27	29	30	32	34	35	36	38	39	40	42	43
8°00'	23	25	27	28	30	31	33	34	35	37	38	39	40
9°00'	22	24	25	27	28	30	31	32	33	35	36	37	38
10°00'	21	22	24	25	27	28	29	31	32	33	34	35	36
11°00'	20	21	23	24	26	27	28	29	30	31	32	33	34
12°00'	19	20	22	23	24	26	27	28	29	30	31	32	33

Appendix A - Maximum Allowable Operating Speeds For Curved Track

FRA TRACK SAFETY STANDARDS

Class of	Type of track	Required frequency track
1,2,3	Main track and sidings.	**Weekly** with at least 3 calendar days interval between inspection, or **before use**, if the track is used less than once a week, or **twice weekly** with at least 1 calendar day interval between inspections, if the track carries passenger trains or more than 10 million gross tons of traffic during the preceding calendar year.
1,2,3	Other than main track and sidings.	**Monthly** with at least 20 calendar days interval between inspections.
4,5,6		**Twice weekly** with at least 1 calendar day interval between inspection.

(d) If the person making the inspection finds a deviation from the requirements of this part, he shall immediately initiate remedial action.

‡ 213.235 Switch and track crossing inspections.

(a) Except as provided in paragraph (b) of this section, each switch and track crossing must be inspected on foot at least monthly.

(b) In the case of track that is used less than once a month, each switch and track crossing must be inspected on foot before it is used.

‡ 213.237 Inspection of rail.

(a) In addition to the track inspections required by ‡ 213.233, at least once a year a continuous search for internal defects must be made of all jointed and welded rails in classes 4 through 6 track, and class 3 track over which passenger trains operate. However, in the case of new rail, if before installation or within 6 months thereafter it is inductively or ultrasonically inspected over its entire length and all defects are removed, the next continuous search for internal defects need not be made until three years after that inspection.

(b) Inspection equipment must be capable of detecting defects between joint bars and in the area enclosed by joint bars.

(c) Each defective rail must be marked with a highly visible marking on both sides of the web and base.

‡ 213.239 Special inspection.

In the event of fire, flood, severe storm, or other occurrence which might have damaged track structure, a special inspection must be made of the track involved as soon as possible after the occurrence.

‡ 213.241 Inspection records.

(a) Each owner of track to which this part applies shall keep a record of each inspection required to be performed on that track under this subpart.

(b) Each record of an inspection under ‡ 213.233 and ‡ 213.235 shall be prepared on the day the inspection is made and signed by the person making the inspection. Records must specify the track inspected, date of inspection an nature of any deviation from the requirements of this part, and the remedial action taken by the person making the inspection. The owner shall retain each record at its division headquarters for at least one year after the inspection covered by the record.

(c) Rail inspection records must specify the date of inspection, the location and nature of any internal rail defects found, and the remedial action taken and the date thereof. The owner shall retain a rail inspection record for at least two years after the inspection and for one year after the remedial action is taken.

(d) Each owner required to keep inspection records under this section shall make those records available for inspection and copying by the Federal Railroad Administration.

APPENDIX B - SCHEDULE OF CIVIL PENALTIES

Appendix B reflects a statement of policy by the Federal Railroad Adminstration in making applicable to Part 213 a specific civil penalty for a violation of particular sections of this Part.

		Violation	Hazardous[1] Violation
Subpart A - General:			
213.5	Responsibility of track owners	$1,000	$2,000
213.7	Designation of qualified persons to supervise certain renewals and inspect track	$500	$1,000
213.9	Clases of track: operating speed limits	$1,000	$2,000
213.11	Restoration or renewal of track under traffic conditions	$1,000	$1,000
213.13	Measuring track not under load	$500	$1,000
Subpart B - Roadbed:			
213.33	Drainage	$500	$1,000
213.37	Vegetation	$500	$1,000
Subpart C - Track Geometry:			
213.53	Gage	$750	$1,500
213.55	Alinement	$750	$1,500
213.57	Curves, elevation and speed limitations	$750	$1,500
213.59	Elevation of curved track; runoff	$750	$1,500
213.61	Curve data for classes 4 through 6	$500	$1,000
213.63	Track surface	$750	$1,500
Subpart D - Track Structure:			
213.103	Ballast; general	$500	$1,000
213.105	Ballast; disturbed track	$500	$1,000

FRA TRACK SAFETY STANDARDS

213.109 Crossties	$750	$1,500
213.113 Defective rails	$1,000	$2,500
213.115 Rail end mismatch	$500	$1,000
213.117 Rail end batter	$500	$1,000
213.119 Continuous welded rail	$500	$1,000
213.121 Rail joints		
213.121a	$500	$1,000
213.121b	$500	$1,000
213.121c	$1,000	$2,500
213.121d	$500	$1,000
213.121e	$500	$1,000
213.121f	$500	$1,000
213.121g	$500	$1,000
213.123 Tie plates	$500	$1,000
213.125 Rail Anchoring	$750	$1,500
213.127 Track spikes	$750	$1,500
213.129 Track shims	$500	$1,000
213.131 Planks used in shimming	$500	$1,000
213.133 Turnouts and track crossings generally	$500	$1,000
213.135 Switches	$500	$1,000
213.137 Frogs	$500	$1,000
213.139 Spring rail frogs	$750	$1,500
213.141 Self-guarded frogs	$500	$1,000
213.143 Frog guard rails and guard faces; gage	$500	$1,000

Subpart E - Track Appliance and Track-Related Devices

	Violation	Hazardous Violation
213.205 Derails	$500	$1,000
213.207 Switch heaters	$500	$1,000

Subpart F - Inspection

213.233 Track inspections	$500	$1,000
213.235 Switch and track crossings inspections	$500	$1,000
213.237 Inspection of rail	$750	$1,500
213.239 Special inspections	$500	$1,000
213.241 Inspection records	$750	$1,500

Note: (1)

For the purpose of this appendix, a hazardous violation is one involving an immediate hazard or death or injury, or when an actual accident, death or injury results from the violation. The Administrator reserves the authority to assess the maximum penalty of $2,500 for a violation of any section or subsection contained in part 213.

APPENDIX C

DEFECT CODE	DESCRIPTION
7.01	No written record of names of qualified persons to supervise restoration and renewals of track under traffic and/or inspect track for defects.
11.01	Proper qualified supervision not provided at work site when track is being restored or renewed under traffic conditions.
33.01	Drainage or water carrying facility not maintained.
33.02	Drainage or water carrying facility obstructed by debris.
33.03	Drainage facility collapsed.
33.04	Drainage or water carrying facility obstructed by vegetation.
33.05	Drainage or water carrying facility obstructed by silting.
33.06	Drainage facility deteriorated to allow subgrade saturation.
33.07	Uncontrolled water undercutting track structure or embankment.
37.01	Combustible vegetation around track carrying timber structures.
37.02	Vegetation obstructs visibility of railroad signs and fixed signals.
37.03	Vegetation obstructs passing of day and night signals by railroad employees.
37.04	Vegetation interferes with railroad employees performing normal trackside duties.
37.05	Vegetation prevents proper functioning of signal and/or communication lines.
37.06	Excessive vegetation at train order office, depot, interlocking plant, carman's building, etc., prevents employees on duty from visually inspecting moving equipment when their duties so require.
37.07	Excessive vegetation at train meeting points prevents proper inspection by railroad employees of moving equipment.
37.08	Excessive vegetation in toepaths and around switches where employees are performing normal trackside duties.
37.09	Vegetation brushing sides of rolling stock.
53.01	Gage dimension exceeds allowable for tangent track.
53.02	Gage dimension is less than allowable for tangent track.

DEFECT CODE	DESCRIPTION
53.03	Gage dimension exceeds allowable for curved track.
53.04	Gage dimension is less than allowable for curved track.
55.01	The alinement of curved track exceeds the allowable deviation.
55.02	The alignment of curved track exceeds the allowable deviation.
61.01	Owner of track fails to have and/or maintain a record of each curve in class 4 through 6 track.

FRA TRACK SAFETY STANDARDS

61.02 Owner's record is incomplete.
63.01 Runoff in any 31 feet of rail at end of raise exceeds allowable.
63.02 Deviation from uniform profile on either rail exceeds allowable.
63.03 Deviation from designated elevation of spirals exceeds allowable.
63.04 Variation in cross level on spirals in any 31 feet exceeds the allowable.
63.05 Deviation from zero cross level at any point on tangent exceeds allowable.
63.06 Deviation from designated elevation on curves between spirals exceeds allowable.
63.07 Difference in cross level between any two points less than 62 feet on tangents exceeds allowable.
63.08 Difference in cross level between any two points less than 62 feet on curves between spirals exceeds allowable.
103.01 Insufficient ballast.
103.02 Fouled ballast.
105.01 Disturbed track not examined by qualified employee and proper action taken.
109.01 Less than allowable minimum number of non-defective ties per 39 feet.
109.02 Less than allowable minimum number of non-defective ties under a joint.
109.03 Distance between non-defective ties exceeds allowable.
109.04 Crossties used in place of switch ties for other than emergency or temporary installation.
109.05 Crossties used in place of switch ties beyond allowable duration.
113.01 Transverse fissure.
133.02 Compound fissure.
113.03 Horizontal split head.
113.04 Vertical split head.
113.05 Split web.
113.06 Piped rail.
113.07 Bolt hole crack.
113.08 Head web separation.
113.09 Broken base.
113.10 Detail fracture.
113.11 Engine burn fracture.
113.12 Ordinary break.
113.13 Broken or defective weld.
113.14 Damaged rail.
113.15 Shelly spots.
113.16 Head checks.
113.17 Engine burn (not fracture).

DEFECT CODE	DESCRIPTION
113.18	Mill defect
113.19	Flaking.
113.20	Slivered.
113.21	Corrugated.
113.22	Corroded.
115.01	Rail end mismatch on tread of rail exceeds allowable.
115.02	Rail end mismatch on gage side of rail exceeds allowable.
117.01	Rail end batter exceeds allowable.

119.01 Failure to adjust CWR for proper temperature range leading to excessive compressive or tensile stresses.
119.02 Disturbing CWR at temperatures above laying or adusted temperature leading to track distortion.
121.01 Rail joint not of proper design or dimension.
121.02 Crack or broken joint bar in Class 3 through 6 track (other than center break).
121.03 Cracked or broken (center break) joint bar.
121.04 Worn joint bar allows vertical movement of rail in joint in Class 3 through 6 track.
121.05 Less than two bolts per rail at each joint for conventional jointed rail in class 2 through 6 track.
121.06 Less than one bolt per rail at each joint for conventional jointed rail in Class 1 track.
121.07 Less than two bolts per rail at any joint in continuous welded rail.
121.08 Loose joint bars.
121.09 Torch cut or burned bolt hole in joint bar in Class 3 through 6 track.
121.10 Torch cut or burned bolt hole in rail in Class 3 through 6 track.
123.01 Insufficient tie plates in Class 3 through 6 track.
123.02 Shoulder of tie plate under base of rail.
125.01 Excessive longitudinal rail movement.
125.02 Anchors not properly installed.
129.01 Shims smaller than tie plate.
129.02 Shims in improper location.
129.03 Shims not spiked properly.
129.04 Rail improperly braced.
131.01 Planks of insufficient width.
131.02 Planks of insufficient length.
131.03 Planks improperly spiked.
131.04 Shims not removed and track resurfaced.
133.01 Loose, worn or missing switch clips.
133.02 Loose, worn or missing clip bolts (transit, side jaw, eccentric, vertical).
133.03 Loose, worn or defective connecting rod.
133.04 Loose, worn or defective connecting rod fastenings.
133.05 Loose, worn or defective switch rod.
133.06 Loose, worn or missing switch rod bolts.
133.07 Worn or missing cotter pins.
133.08 Loose or missing rigid rail braces.
133.09 Loose or missing adjustable rail braces.
133.10 Missing switch, frog or guard rail plates.

DEFECT CODE	DESCRIPTION
133.11	Loose or missing switch point stops.
133.12	Loose, worn or missing frog bolts.
133.13	Loose, worn or missing guard rail bolts.
133.14	Loose, worn or missing guard rail clamps, wedge, separator block or end block.
133.15	Obstruction between switch point and stock rail.
133.16	Obstruction in flangeway of frog.
133.17	Obstruction in flangeway of guard rail.
133.18	Insufficient anchorage to restrain rail movement

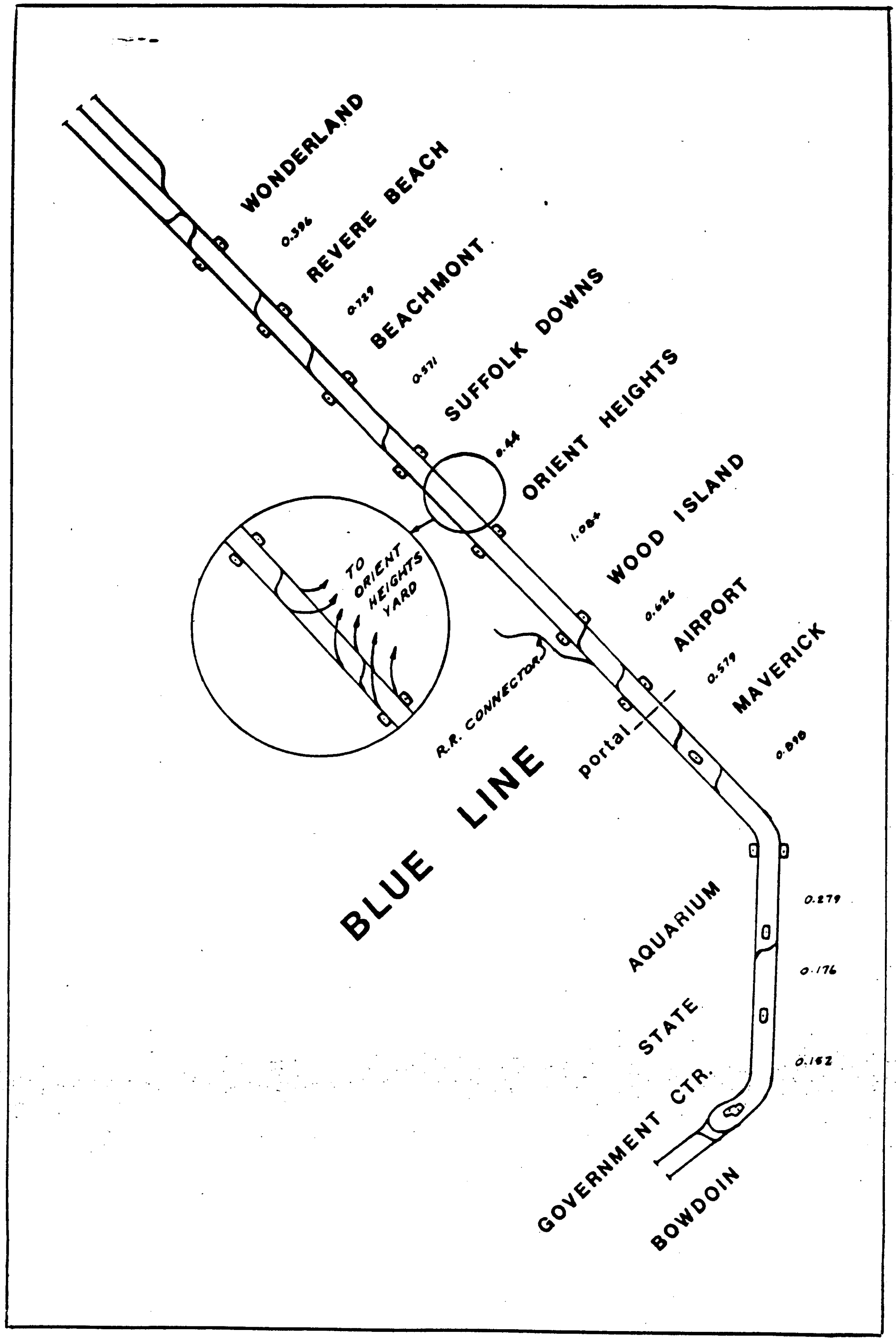
FRA TRACK SAFETY STANDARDS

133.19	Flangeway less than 1 1/2 inches wide.
135.01	Stock rail not securely seated in switch plates.
135.02	Stock rail canted by overtightening rail braces.
135.03	Improper fit between switch point and stock rail.
135.04	Outer edge of wheel contacing gage side of stock rail.
135.05	Excessive lateral or vertical movement of switch point.
135.06	Heel of switch insecure.
135.07	Insecure switch stand or switch machine.
135.08	Insecure connecting rod.
135.09	Throw lever operable with switch lock or keeper in place.
135.10	Switch position indicator not clearly visible.
135.11	Unusually chipped or worn switch point.
135.12	Improper switch closure due to metal flow.
137.01	Insufficient flangeway depth.
137.02	Frog point chipped, broken or worn in excess of allowable.
137.03	Tread portion of frog worn in excess of allowable.
139.01	Outer edge of wheel contacting side of spring wing rail.
139.02	Toe of wing rail not fully bolted and tight.
139.03	Ties under toe or wing rail not solidly tamped.
139.04	Bolt hole defect in frog.
139.05	Head and web separation in frog.
139.06	Insufficient tension in spring to hold wing rail against point rail.
139.07	Excessive clearance between holddown housing and horn.
141.01	Raised guard worn excessively.
141.02	Frog point rebuilt before restoring guarding face.
143.01	Guard check less than allowable.
143.02	Guard face gage exceeds allowable.
205.01	Derail not clearly visible.
205.02	Derail operable when locked.
205.03	Remotely controlled derail not actuated when lever is operated and latched.
205.04	Improper size derail.
205.05	Improperly installed derail.
205.06	Loose, worn or defective parts of derail.

DEFECT CODE	DESCRIPTION
207.01	Switch heater interferes with switch operation.
207.02	Operation of switch heater jeopardizes the safety of railroad equipment.
233.01	Track inspected by other than qualified designated individual.
233.02	Track being inspected at excessive speed.
233.03	Failure to inspect at required frequency.
233.04	Failure to initiate remedial action for deviations found.
235.01	Failure to inspect switches at required frequency.
235.02	Failure to inspect track crossings at required frequency.
237.01	Failure to inspect rail for internal defects at required frequency.
237.02	Failure of equipment to inspect rail at joints.
237.03	Defective rail not marked properly.
239.01	Failure to make special inspections when required.
241.01	Failure to keep records as required.
241.02	Failure of inspector to complete report at time of inspection.
241.03	Failure of inspector to sign report.
241.04	Failure of inspector to provide required information.
241.05	Failure of rail inspection records to provide required information.
241.06	Failure to make record available for copying and inspection.

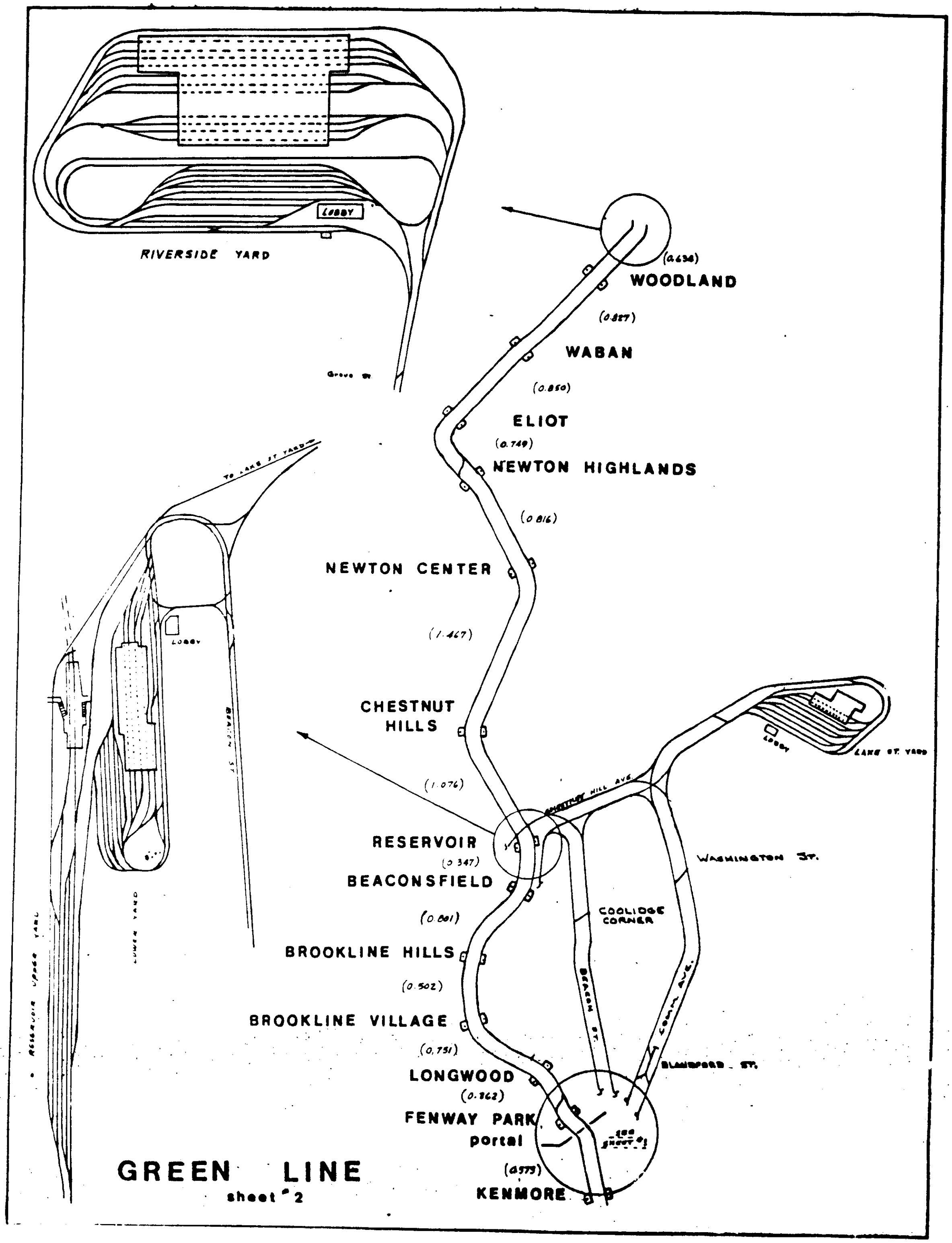
Appendix D-1

BLUE LINE TRACK DISTANCE BETWEEN STATIONS



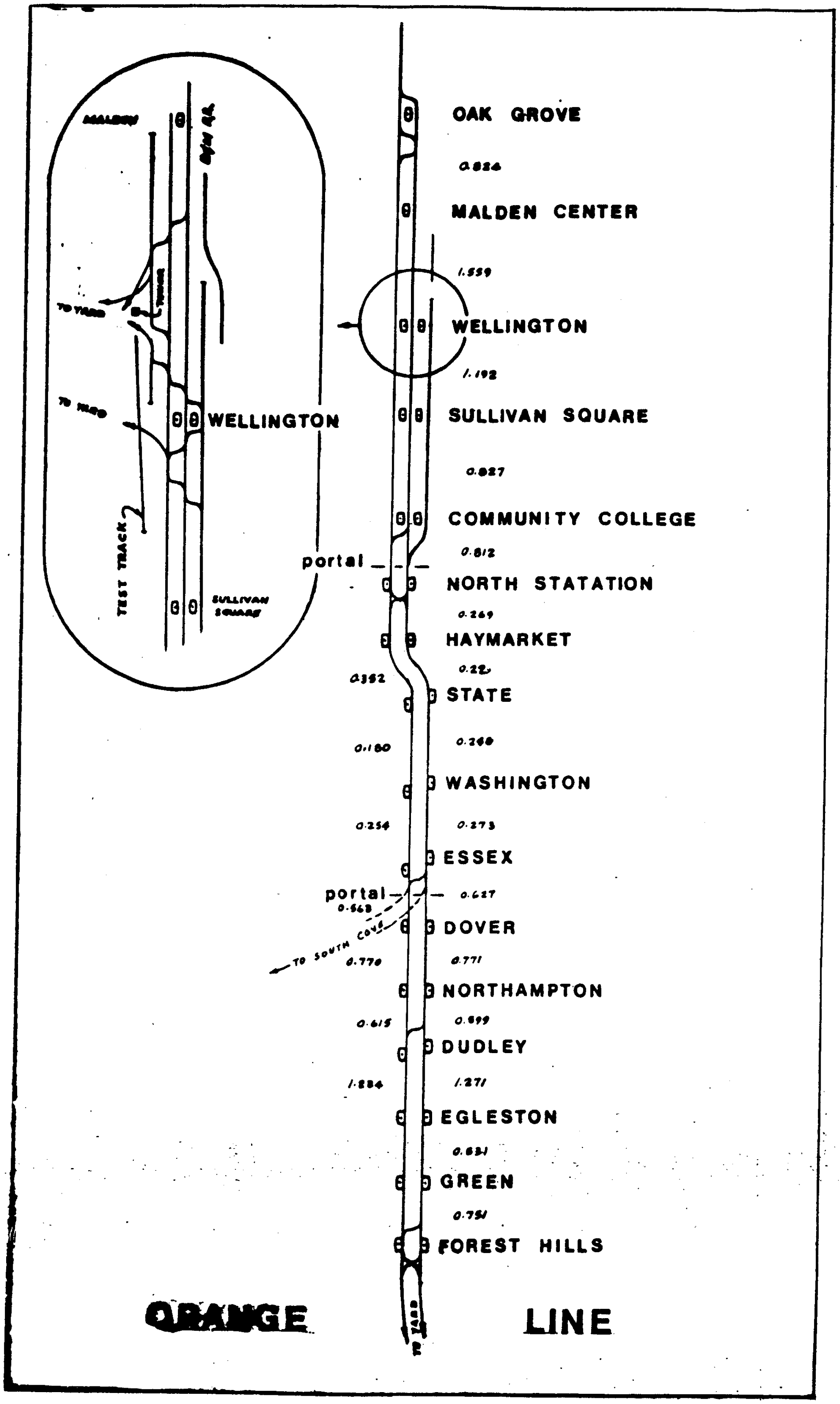
Appendix D-4 (Continued)

GREEN LINE TRACK DISTANCE BETWEEN STATIONS



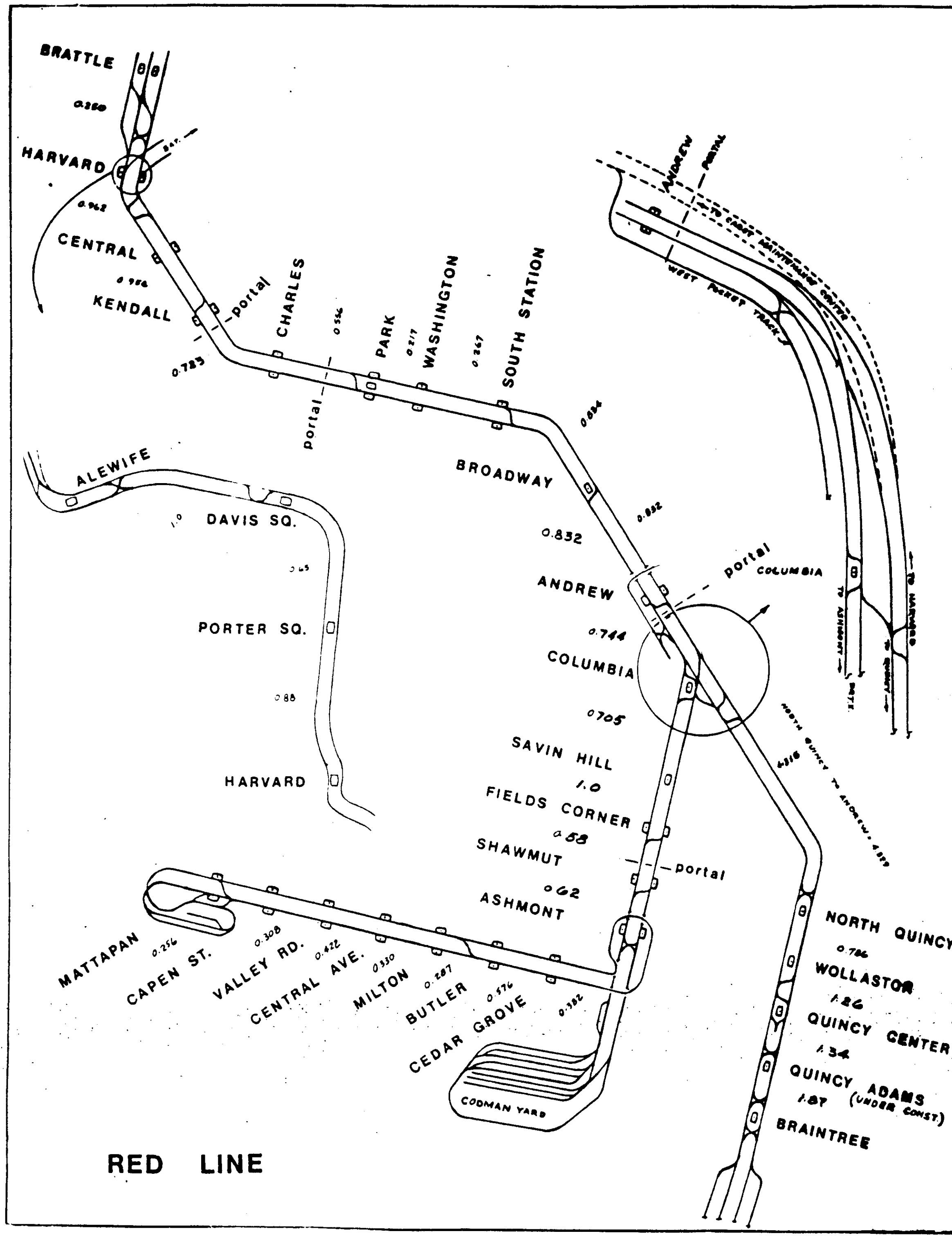
Appendix D-2

ORANGE LINE TRACK DISTANCE BETWEEN STATIONS



Appendix D-3

RED LINE TRACK DISTANCE BETWEEN STATIONS



Appendix D-4

GREEN LINE TRACK DISTANCE BETWEEN STATIONS