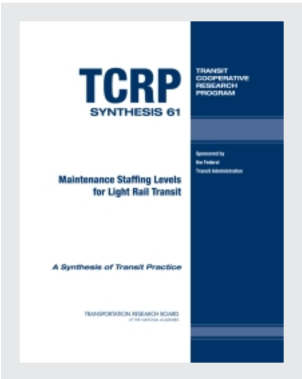

Maintenance Staffing Levels for Light Rail Transit

DETAILS

41 pages | | PAPERBACK
ISBN 978-0-309-09757-4 | DOI 10.17226/13547

AUTHORS

Richard Stanger; Transportation Research Board

TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP SYNTHESIS 61

Maintenance Staffing Levels for Light Rail Transit

A Synthesis of Transit Practice

CONSULTANT
RICHARD STANGER
Manuel Padron & Associates
Los Angeles, California

TOPIC PANEL

LEE BRODIE, *Dallas Area Rapid Transit*
HENRY DAVIS, *Southeastern Pennsylvania Transportation Authority*
MARK GROVE, *Tri-County Metropolitan Transportation District*
FRANK N. LISLE, *Transportation Research Board*
LITTLETON C. MacDORMAN, *Arlington, Virginia*
CLAIRE E. McKNIGHT, *City College of New York*
PAUL O'BRIEN, *Utah Transit Authority*
PETER D. TERESCHUCK, *San Diego Trolley, Inc.*
CARLOS GARAY, *Federal Transit Administration* (Liaison)

SUBJECT AREAS
Public Transit

Research Sponsored by the Federal Transit Administration in Cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2005
www.TRB.org

TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academy of Sciences, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by TRB. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

TCRP SYNTHESIS 61

Project J-7, Topic SE-03
ISSN 1073-4880
ISBN 0-309-09757-6
Library of Congress Control Number 2005929992

Price $16.00

NOTICE

The project that is the subject of this report was a part of the Transit Cooperative Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the project concerned is appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the Transit Development Corporation, the National Research Council, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

Special Notice

The Transportation Research Board of The National Academies, the Transit Development Corporation, the National Research Council, and the Federal Transit Administration (sponsor of the Transit Cooperative Research Program) do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the clarity and completeness of the project reporting.

Published reports of the

TRANSIT COOPERATIVE RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. William A. Wulf are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is a division of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation through research. In an objective and interdisciplinary setting, the Board facilitates the sharing of information on transportation practice and policy by researchers and practitioners; stimulates research and offers research management services that promote technical excellence; provides expert advice on transportation policy and programs; and disseminates research results broadly and encourages their implementation. The Board's varied activities annually engage more than 5,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

TCRP COMMITTEE FOR PROJECT J-7

CHAIR
FRANK T. MARTIN
PBS&J, Tallahassee, FL

MEMBERS
DEBRA W. ALEXANDER
Capital Area Transportation Authority, Lansing, MI
DWIGHT FERRELL
The Ferrell Group, Richardson, TX
MARK W. FURHMANN
Metro Transit, Minneapolis, MN
ROBERT H. IRWIN
British Columbia Transit, Victoria, BC, Canada
PAUL J. LARROUSSE
National Transit Institute, New Brunswick, NJ
WADE LAWSON
South Jersey Transportation Authority, Atlantic City, NJ
DAVID A. LEE
Connecticut Transit, Hartford, CT
DAVID PHELPS
Consultant, Moneta, VA
HAYWARD M. SEYMORE, III
Laidlaw Transit Services, Inc., University Place, WA
PAM WARD
Ottumwa Transit Authority, Ottumwa, IA
JOEL R. WASHINGTON
Washington Metropolitan Area Transit Authority, Washington, DC

FTA LIAISON
KAREN FACEN
Federal Highway Administration

TRB LIAISON
PETER SHAW
Transportation Research Board

COOPERATIVE RESEARCH PROGRAM STAFF
ROBERT J. REILLY, *Director, Cooperative Research Programs*
CHRISTOPHER W. JENKS, *Manager, TCRP*
EILEEN P. DELANEY, *Director of Publications*

TCRP SYNTHESIS STAFF
STEPHEN R. GODWIN, *Director for Studies and Information Services*
JON WILLIAMS, *Manager, Synthesis Studies*
DONNA L. VLASAK, *Senior Program Officer*
DON TIPPMAN, *Editor*
CHERYL KEITH, *Senior Secretary*

FOREWORD

By Staff
Transportation
Research Board

Transit administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the transit industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire transit community, the Transit Cooperative Research Program Oversight and Project Selection (TOPS) Committee authorized the Transportation Research Board to undertake a continuing study. This study, TCRP Project J-7, "Synthesis of Information Related to Transit Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute a TCRP report series, *Synthesis of Transit Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

This synthesis documents light rail maintenance staffing practices and factors important in their development at U.S. transit agencies. It covers the areas of maintenance functions, new light rail start-up, and management in attempting to give better insight into the variables affecting maintenance staffing. This topic is of interest to transit managers of existing light rail transit (LRT) operations and those involved in the planning or implementing of new LRT lines. It is also of interest to agency directors or general managers and executive or board members who need to understand how the industry accomplishes system maintenance.

A survey was conducted to gather feedback from U.S. transit agency staff working in LRT maintenance. Based on survey results, topical case studies were developed to highlight specific policies and practices at four U.S. agencies—San Diego (CA) Trolley, Inc.; Utah Transit Authority; Tri-County Metropolitan Transportation District of Oregon (TriMet); and the Greater Cleveland (OH) Regional Transportation Authority (RTA). These combine with supplemental information gleaned from FTA's National Transit Database to update and expand on the operating characteristics of U.S. LRT systems.

A panel of experts in the subject area guided the work of organizing and evaluating the collected data and reviewed the final synthesis report. A consultant was engaged to collect and synthesize the information and to write the report. Both the consultant and members of the oversight panel are acknowledged on the title page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

MAINTENANCE STAFFING LEVELS FOR LIGHT RAIL TRANSIT

SUMMARY

A renaissance in light rail transit (LRT) over the last 25 years has resulted in many new systems. Of the 20 existing light rail systems, 15 have been built or substantially renewed since 1980. Another 36 U.S. cities are either planning or implementing new light rail lines. System maintenance plays a large part in keeping operating costs low. Adequate staffing for light rail vehicle fleet maintenance, wayside maintenance, and facilities/equipment maintenance is critical in ensuring a cost-effective system.

Determining maintenance staffing levels is a challenge for all agencies, particularly new agencies with no rail maintenance history. A comparative survey of existing LRT systems may help maintenance managers understand the variables affecting maintenance staffing. The purpose of this synthesis report is to document light rail maintenance staffing practices to guide existing and emerging light rail projects.

The initial approach taken was to review characteristics and operating environments of existing light rail systems to determine if any might clearly influence their maintenance staff levels. However, the analysis indicated that there are no clear relationships between level of staff and common system characteristics. There are too many factors extant to isolate any one as causal. There are also nonquantifiable factors involved including budget constraints, collective bargaining agreements, and management philosophies.

Certain indicators are used by most agencies as benchmarks. The most widely used is the "number of revenue system failures" for light rail vehicle maintenance. However, accurate information on this indicator is lacking, most likely because of the varied definitions of this term in use. Because of its importance to maintenance managers, the industry needs to develop a consistent definition of "revenue system failures." Similarly, some useful non-cost indicator of maintenance of way (wayside maintenance) performance could be selected by the industry as its standard benchmark for this maintenance function.

The second part of the study used a questionnaire to probe how light rail managers themselves felt their agency's maintenance philosophies, policies, or labor relations affected maintenance staffing. Because the range of responses was substantial, the conclusions must be considered general. The main drivers of staff levels are agency policies on quality of service and ongoing experience with manpower availability. Managing these resources has become harder over time owing to gradually increasing time-off rules, budget constraints, and difficulty in training staff for broader responsibilities and advancement. Light rail systems do not contract out many maintenance tasks, preferring, for quality control, to do as much as possible with their own resources.

The need for and efficient use of common spare parts was noted by many systems. Although this is difficult to achieve given the number of railcar vendors in the market, the industry might want to select and standardize key components with high failure or replacement rates.

The third part of the study focused on the light rail maintenance staffing of four case study cities: San Diego, Salt Lake City, Portland (Oregon), and Cleveland. They represent a range

of agency types, system ages, climate types, and labor agreements. Based on the evaluation of these systems, overall productivity, as measured by total maintenance employees per unit of common measure (track-mile, peak vehicle, or car-mile), appears to be better with simpler organizations and fewer job classifications.

There also appears to be a fairly consistent range of maintainers-to-manager ratios across the industry, although these vary somewhat by the technical nature of the maintenance function. The study results can be used to confirm whether a staffing plan has a reasonable blend of managers and maintainers.

The staff productivity indicators—employees per unit of measure—vary as well among the agencies surveyed. It was nevertheless possible to recognize possible common ranges. LRT systems can use these common staffing ranges as a check on reasonableness.

CHAPTER ONE

INTRODUCTION

BACKGROUND

Over the last 25 years there has been a revival in light rail transit (LRT) which has resulted in the development of many new systems. Of the 20 existing light rail systems, 15 have been built or substantially revitalized since 1980. Another 36 U.S. cities are either planning or currently implementing light rail lines. System maintenance plays a large role in keeping operating costs low. Adequate staffing for light rail vehicle (LRV) fleet maintenance, wayside maintenance [maintenance of way (MOW)], and facilities and equipment maintenance is critical in ensuring a cost-effective system.

An ongoing challenge for all agencies is determining maintenance staffing levels. It is particularly so for agencies with no rail maintenance history. In spite of 25 years of LRT system development, there is a lack of information on the subject. A comparative survey of existing LRT systems in this synthesis may help maintenance managers understand the variables affecting maintenance staffing.

STUDY PURPOSE AND CONSTRAINTS

The purpose of this synthesis is to document light rail maintenance staffing practices to guide existing and emerging LRT systems. Its objective is to provide information on industry maintenance staffing practices to three groups. The first group is the managers of LRT maintenance functions, so that they can compare their staff levels with others in the industry. The second group is those involved in a new light rail start-up. Although they may also use other staffing recommendations, they would be able to check those recommendations against industry practices. The third group comprises system directors, executives, or board members, who need to understand how the industry accomplishes system maintenance. Proposed staffing policies, requests for additional staff, or pending reductions in staff levels could then be made with better understanding of maintenance practices.

This synthesis relied on responses to surveys and questionnaires sent to individuals working in LRT maintenance. The response rate was 50%. The four agencies visited for the case studies were also very helpful. However, it should be noted at the outset that although the sample size is too small to allow any meaningful statistical analysis, the information provided by the participants is useful nevertheless.

Ideally, every agency is doing the optimal amount of maintenance necessary. This would allow the best “apples-to-apples” comparison. Actually, budgetary pressures often dictate that maintenance be deferred. These pressures, and others like it, cannot be extracted from the data available.

STUDY APPROACH

This synthesis documents LRT maintenance staffing levels and the factors important in their development. In addition to this introduction, it is divided into four chapters. Chapter two updates and expands on the operating characteristics of U.S. light rail systems, as reported in the FTA’s National Transit Database (NTD). This review adds information that may affect the level of maintenance. The information includes characteristics of LRVs in use, characteristics of the operating environment and guideway design, number and type of stations, and number of auxiliary facilities. It is intended to be an overview of the factors affecting maintenance staffing.

Chapter three discusses the results of a questionnaire sent to each LRT system. The questionnaire addresses such topics as the system’s basic maintenance philosophy; its practice regarding contracted maintenance; labor issues; and vehicle, wayside, and facilities maintenance issues. The discussion of questionnaire responses provides a synopsis of industry practices.

Chapter four presents in detail how four light rail agencies maintain their systems, why certain approaches are implemented, and what staff levels are used. The latter information includes the ratio of system maintainers to managers by maintenance function and the labor input to maintain one LRV or 1 mi of track. Available staff information from other agencies is included.

Chapter five presents conclusions drawn from the information contained in the previous sections.

CHAPTER TWO

CHARACTERISTICS OF EXISTING LIGHT RAIL TRANSIT SYSTEMS RELATED TO SYSTEM MAINTENANCE

There are 20 light rail systems operating in the United States. APTA lists more, but this study excluded those smaller electric rail operations not used primarily for commuting. Of the 20 systems, one is run by a contract operator (the Hudson–Bergen Line in northern New Jersey), making some of its operating information proprietary. In all, 11 of the 20 systems responded to the survey of system characteristics and the questionnaire. To supplement the 2004 information obtained from these 11 properties, information on 8 of the remaining 9 systems was taken from the 2003 NTD. Because the Minneapolis light rail system opened in mid-2004 and had no full-year statistics to report it was the only light rail system not studied.

OVERVIEW OF STATISTICS

Tables 1–3 provide the characteristics of each operating LRT system that pertain to system maintenance. There is one table each for LRV maintenance (Table 1), MOW (Table 2), and stations and facilities (Table 3). The top grouping in each table is the 2004 survey information supplied by the responding agencies, the bottom grouping is 2003 information taken from the 2003 NTD. Because the NTD does not ask rail systems to report certain information that was believed to be important for this synthesis, some sections of the lower grouping are blank.

Table 1 shows information on LRV maintenance. Each system's operating environment typically determines the physical design of its LRV: length, width, articulation, maximum speed, and floor level. Nevertheless, most light rail systems use an articulated LRV design. With recent vehicles there has generally been an increase in the maximum operating speeds of LRVs, from 50 mph to 65 mph. A recent development in vehicle design is the introduction of the low-floor railcar, allowing passengers to board the vehicle without climbing steps.

A number of factors may influence the level of LRV maintenance; among them are:

- Operating environment—more street running results in more stop-and-go operation and more accidents. Extreme weather conditions may also result in more maintenance.
- Type of vehicle—technically advanced vehicles most likely require more maintenance.
- Experience of the manufacturer—new vehicle designs or a less experienced vendor may result in additional ongoing maintenance. Proprietary parts may be costly to obtain.
- Labor constraints—work rules may affect efficiency, and high employee turnover rates lower staff productivity.
- Staff experience—new systems may have higher costs because staff is less experienced or is purposefully overstaffed for planned expansions.
- Budget constraints—systems often experience budget constraints that limit the amount of maintenance performed.
- Spare ratios—a higher spare ratio increases apparent maintenance staff per peak vehicle.

Table 2 presents factors involved in the maintenance of the guideway including the track, traction power (substations and overhead catenary), and signal and communication subsystems. Light rail systems operate primarily at-grade to reduce capital investment. Operating speeds increase by protecting the at-grade tracks as much as practical from automobile traffic. In the best case scenario, light rail trains operate on a dedicated right-of-way with only occasional street crossings. A number of LRT systems achieve this. Buffalo has the highest percentage of track-miles in subway by far (78%); more than half of all systems have no subway segments.

Some of the factors that influence guideway maintenance include:

- Climate conditions—Significant range of temperatures or substantial amounts of rain and snow may result in more maintenance.
- Operating conditions—Significant on-street running in mixed traffic or on/in structure constrains maintenance of trackway and traction power systems.
- Age of infrastructure—Older systems require more maintenance than newer ones because more things wear out over time.
- Labor terms—Work rules may affect efficiency and high worker turnover results in a less experienced staff.
- Budget constraints—Systems often experience budget constraints that limit maintenance performed.

TABLE 1
VEHICLE MAINTENANCE CHARACTERISTICS AND COSTS

System	Year of Start-Up	Equipment Type (maximum speed)*	Vehicles Operated in Maximum Service	Total Active Fleet	Average Age of Fleet (Years)	Total Annual Revenue Mechanical Failures	Annual Vehicle Revenue-Miles	Revenue Vehicle-Miles per Revenue Mechanical Failure	Annual Labor Hours for Inspection and Maintenance	Annual Vehicle Maintenance Expenses	Maintenance Cost per Vehicle Revenue-Mile	Maintenance Cost per Vehicle Operated in Maximum Service
FY2004 STATISTICS FROM STUDY SURVEY												
										(2004$)	(2004$)	(2004$)
Buffalo	1985	HL/LL (?)	23	27	19	555	765,082	1,379	39,520	$2,249,087	$2.94	$97,786
Cleveland	1989[a]	ART (55 mph)	16	48	22	90	954,081	10,601	64,254	$2,391,337	$2.51	$149,459
Dallas	1996	95 ART, 1 LF (65 mph)	84	95	6	135	5,372,890	39,799	94,556	$7,917,463	$1.47	$94,256
Denver[c]	1994	ART (55 mph)	45	49	5	0	3,764,205	0	76,222	NP	NP	NP
Houston	2003	LF (?)	15	17	1	119	478,398	4,020	19,741	$2,525,300	$5.28	$168,353
Philadelphia	1980[b]	not-ART (?)	115	141	24	825	1,598,000	1,937	131,000	$10,800,000	$6.76	$93,913
Pittsburgh	1985	not provided	48	70	10.9	454	1,224,844	2,698	199,360	$9,537,598	$7.79	$198,700
Portland	1986	30% HF, 70% LF (?)	83	95	9.2	1,990	6,775,188	3,405	107,440	$13,406,170	$1.98	$161,520
Salt Lake City	1999	ART (55 mph)	39	46	5.6	72	2,355,429	32,714	49,213	$3,680,000	$1.56	$94,359
San Diego	1979	ART (50 mph)	83	123	14.2	150	7,078,660	47,191	153,574	$8,056,896	$1.14	$97,071
San Francisco	1912	ART (?)	110	151	4	2,583	5,616,212	2,174	791,932	NP	NP	NP
FY2003 STATISTICS FROM NATIONAL TRANSIT DATABASE												
										(2003$)	(2003$)	(2003$)
Baltimore	1992	—	49	53	8.3	96	2,634,883	27,447	83,677	$4,935,321	$1.87	$100,721
Boston	1890	—	155	199	19.1	1,190	5,689,117	4,781	345,280	$15,790,689	$2.78	$101,875
Hudson-Bergen	2002	—	15	29	14.6	N/A	704,864	N/A	N/A	$6,142,483	$8.71	$409,499
Los Angeles	1990	—	69	102	8.8	2,489	5,781,961	2,323	384,591	$16,255,679	$2.81	$235,590
Newark	1930	—	12	16	34.5	45	478,913	10,643	136,146	$4,927,404	$10.29	$410,617
Sacramento	1988	—	32	36	13.9	40	2,128,498	53,212	160,524	$6,000,779	$2.82	$187,524
Santa Clara	1988	—	41	66	15.6	98	2,466,130	25,165	191,360	$12,406,691	$5.03	$302,602
St. Louis	1991	—	49	65	5.1	297	5,156,197	17,361	84,850	$6,111,400	$1.19	$124,722

Notes: — = NTD did not ask for this information; NP = not provided by agency; N/A = not available (proprietary).
*Notes on equipment type: ART = articulated; LF = low floor; HF = high floor; HL/LL high level, low level.
[a]Cleveland inaugurated its rebuilt LRT system in 1989.
[b]Philadelphia received its rebuilt LRV fleet in 1980. In addition, Philadelphia uses single-ended cab cars in its Central Division, double-ended cabs in its Surburban Division.
[c]Denver's information is from 2003.

TABLE 2
OPERATING ENVIRONMENT AND GUIDEWAY MAINTENANCE CHARACTERISTICS AND COSTS

System	Average Temperature High/Low (°F)	Average Precipitation (inches)	Weather Factor*	Track-Miles At-Grade, Exclusive	Track-Miles At-Grade, with Cross Traffic	Track-Miles At-Grade, Mixed Flow with Cross Traffic	Track-Miles on Structure	Track-Miles on Fill	Track-Miles in Subway	Track-Miles in Open Cut	Total Track-Miles	Directional Route-Miles	Annual Track Maintenance Costs	Annual Track Maintenance Costs per Track-Mile	Annual Power Maintenance Costs	Annual Power Maintenance Costs per Track-Mile
FY2004 STATISTICS FROM STUDY SURVEY																
													(2004$)	(2004$)	(2004$)	(2004$)
Buffalo	81/18	39	4	0	2.8	0	0	0	9.7	0	12.4	6.2	$400,000	$32,258	$875,000	$70,565
Cleveland	83/19	47	4	12.5	14.5	0	0.9	2.0	0	3.1	33.0	16.5	$1,755,000	$53,182	$985,000	$29,848
Dallas	96/34	33	2	79.4	2.5	0	11.5	0	6.2	1.8	101.5	44.5	$1,915,208	$18,869	$6,465,415	$63,699
Denver	88/16	17	3	15.2	4.3	0	3.4	7.0	0	2.2	32.1	31.6	NP	NP	NP	NP
Houston	94/41	48	2	0	19.8	0.2	0	0	0	0	20.0	15.3	$415,211	$20,761	$377,255	$18,863
Philadelphia	87/24	41	4	21.0	145.0	0	0	0	4.0	0	171.0	69.3	NP	NP	NP	NP
Pittsburgh	83/20	37	4	36.8	0.3	4.7	3.0	—	4.0	0	48.8	34.8	$1,781,000	$36,496	$2,320,000	$47,541
Portland	80/34	35	2	14.0	50.0	5.0	2.6	1.0	6.0	10.0	88.6	81.3	$1,946,600	$21,971	$1,863,000	$21,027
Salt Lake City	92/20	16	3	26.3	12.6	0	0	0	0	—	38.9	19.5	$368,800	$9,481	$75,600	$1,943
San Diego	77/48	10	1	0	80.2	8.0	6.0	1.8	0	0.6	96.6	96.6	$1,176,500	$12,179	$1,011,750	$10,474
San Francisco	70/46	20	1	5.0	6.0	48.0	0	0	15.0	0	74.0	72.9	NP	NP	NP	NP
FY2003 STATISTICS FROM NATIONAL TRANSIT DATABASE																
													(2003$)	(2003$)	(2003$)	(2003$)
Baltimore	88/24	41	4	37.0	10.0	3.0	2.0	0	0	0	52.0	57.6	—	—	—	—
Boston	82/22	43	4	29.0	29.0	2.0	4.0	0	14.0	0	78.0	51.0	—	—	—	—
Hudson-Bergen	85/26	46	4	11.0	7.0	2.0	0	0	0.0	0	20.0	16.6	—	—	—	—
Los Angeles	82/48	14	1	4.0	31.0	0	12.0	24.0	0	1.0	87.0	82.4	—	—	—	—
Newark	85/26	46	4	6.0	0	0	0	0	3.0	0	9.0	8.3	—	—	—	—
Sacramento	93/38	17	1	9.9	19.4	6.8	1.8	1.5	0	0	39.4	40.7	—	—	—	—
Santa Clara	70/46	20	1	12.0	37.0	0	1.0	7.0	1.0	0	58.0	58.4	—	—	—	—
St. Louis	89/21	37	4	44.0	1.0	0	5.0	10.0	11.0	3.0	74.0	68.8	—	—	—	—

Notes: — = NTD did not ask for this information; NP = not provided by agency.
Shaded areas indicate estimated by agency.
*Weather factor: 1 = no freezing, little precipitation; 2 = no freezing, more precipitation; 3 = freezing, little precipitation; 4 = freezing, more precipitation; 5 = very cold in winter.

TABLE 3
STATION AND FACILITIES CHARACTERISTICS AND MAINTENANCE COSTS

System	Stations At-Grade	Stations on Structure	Stations on Fill	Stations in Open Cut	Stations in Subway	Total Stations	Annual Station Maintenance Costs	Annual Station Maintenance Costs per Station	Number of TVMs	Annual TVM Maintenance Costs	Annual Maintenance Cost per TVM	Done In-House?	Number of Rail Maintenance Facilities	Annual Cost for Maintenance Facilities Maintenance	Cost per Facility
FY2004 STATISTICS FROM STUDY SURVEY															
							(2004$)	(2004$)		(2004$)	(2004$)			(2004$)	(2004$)
Buffalo	7	0	0	0	8	15	$1,000,000	$66,667	42	$400,000	$9,524	Yes	1	$250,000	$250,000
Cleveland	31	0	0	3	0	34	$1,300,000	$38,235	13	$20,000	$1,538	Yes	1	$291,000	$291,000
Dallas	29	4	0	1	1	35	$3,852,202	$110,063	120	$410,338	$3,419	Yes	1	$253,925	$253,925
Denver	24	0	0	0	0	24	NP	NP	42	$115,757	$2,756	Yes	1	NP	NP
Houston	16	0	0	0	0	16	$704,172	$44,032	58	$443,747	$7,651	Yes	1	$441,306	$441,306
Philadelphia	9	0	0	0	15	24	NP	NP	0	N/A	N/A	N/A	3	$400,000	$133,333
Pittsburgh	0	21	0	0	3	24	$1,200,000	$50,000	0	N/A	N/A	N/A	1	NP	NP
Portland	58	1	1	1	1	62	$2,730,000	$44,032	183	$1,144,500	$6,254	Yes	2	$1,178,000	$589,000
Salt Lake City	23	0	0	0	0	23	$345,000	$15,000	62	$180,000	$2,903	Yes	1	$260,000	$260,000
San Diego*	47	2	0	0	0	49	$2,229,000	$45,490	119	$967,000	$8,126	Yes	2	$1,341,300	$670,650
San Francisco	0	0	0	0	9	9	NP	NP	NP	NP	NP	NP	2	NP	NP
FY2003 STATISTICS FROM NATIONAL TRANSIT DATABASE															
							(2003$)	(2003$)		(2003$)	(2003$)			(2003$)	(2003$)
Baltimore	—	—	—	—	—	32	—	—	—	—	—	—	1	—	—
Boston	—	—	—	—	—	78	—	—	—	—	—	—	4.3	—	—
Hudson-Bergen	—	—	—	—	—	15	—	—	—	—	—	—	1	—	—
Los Angeles	—	—	—	—	—	36	—	—	—	—	—	—	2	—	—
Newark	—	—	—	—	—	11	—	—	—	—	—	—	1	—	—
Sacramento	—	—	—	—	—	29	—	—	—	—	—	—	1	—	—
Santa Clara	—	—	—	—	—	44	—	—	—	—	—	—	1	—	—
St. Louis	—	—	—	—	—	26	—	—	—	—	—	—	2	—	—

Notes: — = NTD did not ask for this information; NP = not provided by agency; N/A = not available; TVM = ticket vending machine.
Shaded areas indicate estimated by agency.
*San Diego's Facilities Maintenance is included in Station Maintenance and Equipment Maintenance is included in MOW, LRV, and Facilities.

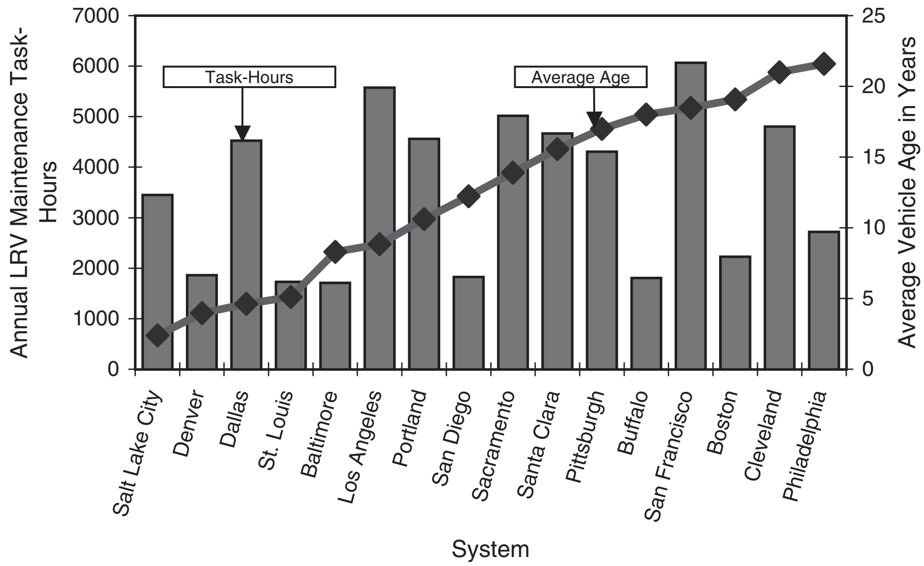

FIGURE 1 Annual LRV maintenance task-hours by average age of vehicle.

Table 3 shows information on each light rail system's stations and maintenance facilities. Most light rail systems have at-grade stations. These stations, however, may be substantial, incorporating weather protection, raised platforms, closed circuit television (CCTV) and public address systems, ticket vending machines (TVMs), artwork, and large parking lots. The stations require ongoing cleaning and maintenance.

SEARCHING FOR PATTERNS

Factors noted in the previous section—and more—influence light rail system maintenance staffing. One would expect relationships between certain factors and LRV maintenance efforts. For example, the average age of the LRV fleet should influence the amount of maintenance needed. The data, however, do not suggest this, as can be seen in Figure 1. (Supporting data are in Appendix A.) Nor could a relationship be found using such indicators as LRV maintenance task-hours versus revenue mechanical failures, maintenance task-hours per track-mile by climate type, and so forth. In short, enough factors are apparently involved in each system's level of LRV maintenance that it is not possible to strongly link any one factor with any particular light rail maintenance effort. Moreover, it is also not possible to perform a meaningful regression analysis given the limited sample. Again, outside influences that could affect maintenance effort might include budget constraints, labor agreements, and organizational structure.

PRODUCTIVITY INDICATORS

A major indicator of productivity is the number of annual task-hours per employee. The fewer annual task-hours available, the more employees it will take to do the work required. The following illustrates the issue. A full-time worker is typically paid for 2,080 h of work annually (52 weeks × 40 h/week). How much of that time is really productive? Table 4 shows a simple analysis done in 1995 by Portland TriMet's vehicle maintenance department. The exact numbers will vary by agency, and clearly some reduction in time (such as shift start-

TABLE 4
TRIMET LABOR PRODUCTIVITY EXERCISE

Description of Time	Hours
Annual Pay Hours (straight time)	2,080
Lost Time Hours:	
Vacation (2.5 week average = 100 h)	(100)
Holidays (6 days)	(48)
Floating holidays (3 days)	(24)
Birthday (1 day)	(8)
Absences (based on department's employee absentee rate of 5%)	(104)
Net After Lost Time Hours	1,796
Non-Task Hours:	
Shift start-up and task assignments (15 min per shift)	
Coffee break (15 min)	
Lunch break (45 min)	
Coffee break (15 min)	
Miscellaneous [e.g., bathroom (5 min)]	
Shift end, clean-up (15 min)	
110 min/shift x 230 shifts/yr x 1 h/60 min = 422 h	(422)
Total Productive Hours per Year:	1,374

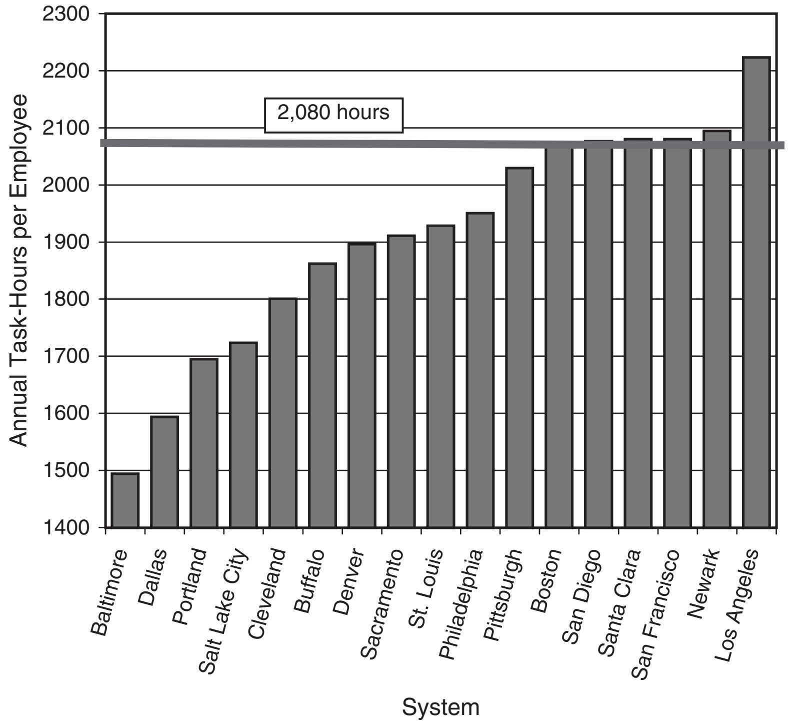

FIGURE 2 Annual LRV maintenance task-hours per employee.

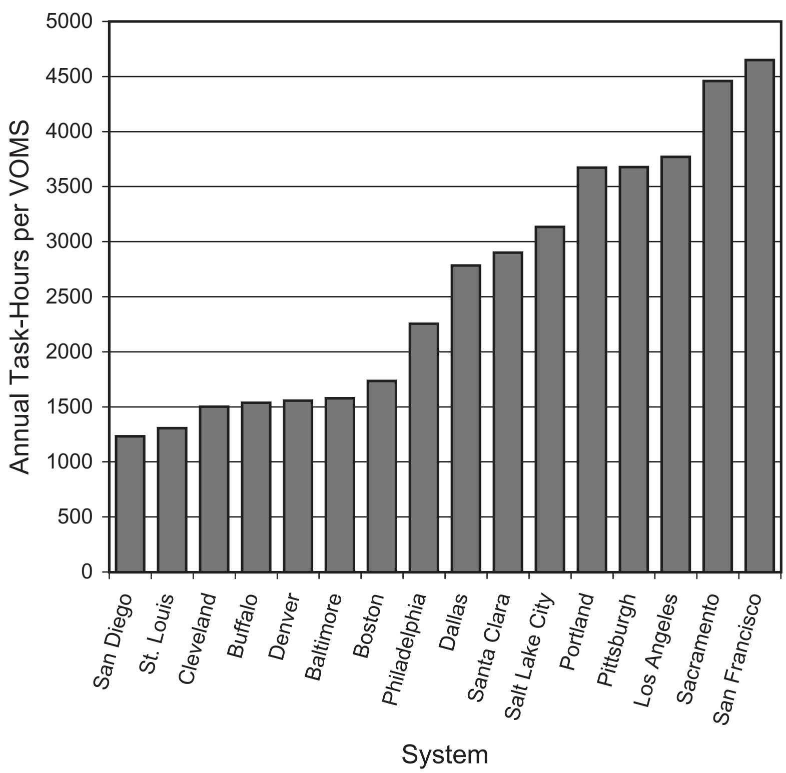

FIGURE 3 Annual maintenance task-hours per vehicle operated in maximum service.

up meetings) could be considered productive. However, it is crucial to note how much productive time is reduced by various factors. Given the vacation, holiday, and sick time an employee receives each year, the maximum number of annual work hours per employee is approximately 1,900 before overtime.

Since the exercise in Table 4 was conducted, Congress passed the Family Medical Leave Act (FMLA), which allows any employee to take additional time off for illness or family-related reasons. Ten additional FMLA days would lessen the 1,374 annual productive hours shown in Table 4 to approximately 1,300.

The inevitable reduction of actual work time illustrated in Table 4 makes it difficult to reconcile some of the "annual maintenance hours per employee" figures reported in the NTD. The reported numbers are shown in Figure 2 for vehicle maintenance employees; reported annual maintenance-hours for nonvehicle maintenance employees are similar. (Supporting data can be found in Appendix A, Table A2.) The systems are listed by increasing number of average annual task-hours per employee. A number of agencies report numbers well in excess of 1,900 h, some exactly 2,080 h. A few have hours above 2,080, which may indicate a substantial amount of overtime per employee. The range is from 72% to 107% of the 2,080-h baseline. The true range among LRT agencies of average annual task-hours per employee is probably narrower and most often toward the lower end.

Another productivity indicator is the annual number of task-hours needed to maintain one unit of product, in this case railcars. The number of annual task-hours to maintain each LRV operated in maximum service (the peak period) as reported in the NTD ranges from 1,230 to 4,650. Figure 3 shows LRT systems from least to most annual LRV maintenance task-hours per vehicle operated in maximum service (VOMS) (see also Appendix A, Table A3). The broad range may result from a number of factors including vehicle design, maintenance budget, work rules, and available spare ratio. For example, the three agencies with the lowest task-hours per vehicle (San Diego, St. Louis, and Cleveland) also have high spare ratios of 48%, 67%, and 320%, respectively. Cleveland has also had a budget problem that has affected its ability to conduct as much maintenance as it wants. On the other hand, Sacramento and Salt Lake City have very tight spare ratios. This may necessitate more maintenance on their well-used fleets. The same broad range occurs for nonvehicle maintenance.

CHAPTER THREE

RESULTS OF QUESTIONNAIRE

Surveys designed to gain a better understanding of underlying philosophies, policies, and other considerations involved in light rail maintenance were received from maintenance staff of 11 agencies. The questions asked and the responses submitted are shown in Appendix B. To the right of the multiple-choice answers in Appendix B is the total of each response. Some of the questions requested that the respondents rank the top two or three possible answers. The two right-most columns of the table note both the number of times a particular response was listed as the most important factor, as well as its weighted total. Responses were weighted as follows: a "1" was given a weight of "3," a "2" a weight of "2," and a "3" a weight of "1." Many questions included "other" as a possible response. The pages following the questionnaire in Appendix B note any comments or clarifications provided.

STAFFING PHILOSOPHIES AND POLICIES

Initial and Ongoing Staff Levels

The first part of the survey probed basic philosophies and policies agencies used initially to establish and then maintain their maintenance staffs. Some noted that their initial staff levels were based in part on consultant recommendations. Other agencies surveyed the industry themselves or used their own historic staff formulas. After the initial staff levels were implemented, ongoing levels were determined based primarily on service quality policies and experience with manpower availability.

Contracting Out

One-third of the respondents had considered contracting out most if not all of the maintenance functions. (The Hudson–Bergen LRT Line contracts out all maintenance as part of a design–build–operate–maintain contract.) The main reason the responding LRT systems gave for not contracting out most maintenance functions were existing collective bargaining agreements. The second most noted reason was the desire to better control maintenance quality.

Maintenance Standards

Most agencies indicated that they had maintenance standards and goals. The majority had standards for interior and exterior cleaning and for periodic maintenance. Two agencies had standards for time allowed before repairing TVMs and before replacing burned-out lamps at stations. Both are important matters to a system's customers. Three noted a standard for the timely repair of broken crossing gates, a clear safety issue. Ninety percent of responding properties indicated that they adequately and consistently monitored the standards and goals they had.

Benchmarking

A majority of the respondents attempted to match their maintenance performance to those of the industry's best systems (benchmarking). Twenty percent benchmarked "quite a bit," and one-third compared themselves with the best in certain specific areas. The two indicators most used for comparison are "miles between revenue vehicle failures" and "maintenance expenses per revenue vehicle-mile." The first, however, is difficult to use because there clearly seems to be a difference in how systems define the term "revenue vehicle failure." Systems ranged from no revenue vehicle mechanical failure every 1,400 vehicle revenue-miles to one every 53,000 miles. This range seems large for systems that have relatively new LRVs. "Maintenance expenses per revenue vehicle-mile" is also an indicator that is difficult to compare because the cost-of-living (and therefore wage rates) vary extensively across the country.

Train Lengths Off-Peak

One way to lower maintenance costs is to minimize unnecessary revenue car-miles. However, this can mean breaking and assembling train lengths two or three times a day. Do LRT operators minimize revenue vehicle-miles in this way? The answer is yes based on the responses obtained. Two of the agencies have off-peak ridership that is too high to allow single-car operation off-peak. Of the nine that can drop cars after the morning peak period, eight do.

LABOR ISSUES

The second group of questions involves labor issues. Labor-related issues were seen affecting maintenance productivity only by some systems. Quality-of-service policies and age of equipment were noted to be more important determinants of maintenance productivity. That the age of equipment was noted is interesting because this review shows no clear industry-wide correlation between age of equipment and maintenance productivity. However, the provisions of labor agreements, expanded benefits and time-off rules in labor contracts, high manpower turnover rates, and new laws like the federal FMLA were all noted by at least one agency or another as a significant productivity issue.

Training

A number of maintenance managers reported that collective bargaining agreements may sometimes affect their ability to advance good workers and/or provide cross-training. These agreements also can make it more difficult to manage vacation, sick, and unscheduled time off. To encourage better attendance maintenance managers often give financial bonuses for good attendance over a given period of time. Other incentives mentioned included "earned" days off for good attendance, counting unused sick days toward pension, and ad hoc awards for performance including attendance. Agencies also provide monetary incentives for meeting or exceeding standards such as fleet availability and on-time performance.

On-the-job training is the primary means of training new workers, and 3 of the 11 agencies use such training exclusively. Other maintenance organizations train employees only for the jobs they perform and fewer still cross-train employees (if allowed) and/or train for advancement. Tight budgets were noted by a number of agencies as a constraint to training.

Overtime

Every agency polled found it more cost-effective to allow overtime than to hire new staff. The reason appears to be the high cost of added benefits, etc. However, there are drawbacks to overtime, especially if there is a significant amount of it. Some managers noted that overtime is less productive than regular time because younger workers tend to work more overtime than older, more experienced workers. Less experienced workers also learn more working with older workers, but there is less opportunity for that during overtime work.

It is worth noting that there are almost no part-time maintenance employees in the industry. Of the 1,867.5 vehicle maintenance full-time equivalents (FTEs) reported in the 2003 NTD, 3 were part-time. Of the 1,520.5 nonvehicle maintenance employees reported, 1 was part-time. Combined, of the 3,388 LRT maintenance employees, 4 were part-time: one-tenth of one percent. The use of part-time employees is clearly not seen as a way to increase productivity.

VEHICLE-RELATED ISSUES

Issues related to rail vehicle maintenance was a third section of the questionnaire. When asked what was considered the single main indicator of good vehicle maintenance the responses were evenly divided between "percent of fleet available for revenue service" and "number of annual revenue service breakdowns." The latter response was also the primary indicator against which agencies could compare themselves. As noted earlier, there is no standard definition of what constitutes a chargeable revenue service breakdown. In two systems, the director of system maintenance (or equivalent position) and the manager of vehicle maintenance defined the term differently.

Issues with Vehicle Design

There is little standardization among the various LRVs procured by transit systems. As such, there are often initial vehicle design issues and/or long-term problems in obtaining spare parts. However, one-half the survey responders believed that their new vehicle's design issues were adequately corrected under warrantee provisions. Correspondingly, one-half believed that the corrections could have gone further. At least one system set up its own internal vehicle engineering group to correct their vehicle's design issues.

Spare Parts

All responding agencies reported serious delays in receiving spare parts, especially from foreign suppliers. All but one noted that lower maintenance costs could be achieved if more LRV parts were common. This is a big problem for LRV maintenance. To help manage the problem, just over one-half of survey respondents stated that they worked with other properties to procure common parts, exchange common parts, and/or exchange information about common parts. (Some maintenance managers indicated that there is evidence that some standardization is occurring among certain manufacturers in recognition of this problem.)

Work Standards

Forty percent of respondents had developed work standards for tasks associated with *preventive* maintenance. Of those that had, 75% indicated that their standards were being adequately monitored. There is a reluctance within the industry to set standards for repair work; no property had developed such work standards. Although some repairs (e.g., body work) depend on the extent of damage, many repairs would seem to lend themselves to an expected length of repair (e.g., window replacement). As to whether more effort was being expended on preventive LRV maintenance or repair of broken subsystems or parts, most systems indicated that they have a good balance between the two.

LRV Maintenance Outsourcing

Most LRV repair is being done in-house. Outsourcing is reserved primarily for specialty repairs. The repair function most outsourced is motor repair/overhaul, followed by upholstery, electronic repair, brake repair/overhaul (in part), and the repair of the maintenance equipment itself. Two systems completing the survey contract for daily car cleaning.

MAINTENANCE OF WAY ISSUES

The fourth section of the survey asked questions about MOW. As with vehicle maintenance, the survey respondents were evenly split when it came to selecting the single main indicator of good guideway maintenance. One-half stated that it was "ride quality determined by periodic testing," the other half that it was the "total of all annual revenue service delays due to track conditions." The definition of revenue service delays was not requested, but there are likely several in use.

Representation

Nine of the 11 systems surveyed had virtually all MOW functions covered by collective bargaining agreements. Respondents indicated that there is no clear evidence that these agreements have significantly affected maintenance costs. Most systems do not get any maintenance help from other public agencies. Those that do primarily receive it in the form of street repairs between mixed-flow light rail tracks.

Contracting Out MOW Functions

Light rail properties contract out some right-of-way maintenance functions. Most contract out landscape maintenance, and 3 of the 11 properties surveyed outsourced communication subsystem repairs (e.g., CCTV, public information systems, and field radios). Several other functions are outsourced by one or more systems: wayside trash removal, graffiti removal, and some signal subsystem repairs.

STATION-RELATED ISSUES

The final section of the questionnaire asked several questions about the maintenance of stations and other fixed facilities. Most systems responded that "a low number of things needing to be fixed based on periodic inspections" as the best indicator of good facilities maintenance. "Cleanliness" came in second.

Public Information Systems

Most systems have either CCTV or automatic train information systems or both. Half of the properties indicated that the maintenance of one or both of these systems was greater than expected.

Contracting Out Station Maintenance Functions

Nine of the 11 properties surveyed had escalators and/or elevators. Of those nine, all but one contracted out their maintenance. The maintenance and repair of the maintenance vehicles and the repair of buildings were also often outsourced. These were the only areas of station maintenance for which more than one or two LRT properties outsourced work. In general, LRT systems contracted out few station maintenance functions.

CHAPTER FOUR

CASE STUDIES

Four light rail systems were chosen for detailed analysis of their maintenance staffs. Two criteria were used in the selection. First, the four represented a range of light rail system ages and organizational structures. Second, they included the four main climate types. The four selected light rail systems were:

- San Diego Trolley, Inc. (SDTI) is the oldest (1981) "new" light rail system and is the only one that operates light rail service only. San Diego has a mild, dry climate.
- The Utah Transit Authority (UTA) operates Salt Lake City's new (1999) light rail service, as part of a two-mode system. Salt Lake City's climate ranges from hot to freezing, but has little rain or snow.
- The Tri-County Metropolitan Transportation District of Oregon (TriMet) operates Portland's light rail service (inaugurated in 1986) as part of a bus–rail transit system. Portland has a cool, wet climate.
- The Greater Cleveland Regional Transit Authority's (RTA's) older, established Shaker Heights Line was substantially renovated in 1989 and is operated as part of a three-mode transit service. Cleveland's climate ranges from hot to cold and gets a great deal of rain and snow.

Each of the case study systems was visited and discussions were held with the director of light rail maintenance (or equivalent) and most maintenance managers. Information was collected on the organizational structure of the light rail maintenance staff, on each maintenance job title and function, and on the number of manager, labor, and clerical positions employed. This information was categorized by the following functional areas:

- LRV maintenance,
- Track maintenance,
- Substation and overhead catenary (power) maintenance,
- Signal and communication systems (signal) maintenance,
- Station maintenance,
- Facilities maintenance,
- Fare equipment maintenance,
- Stores (parts) management, and
- Maintenance administration (if needed).

In cases where maintenance functions may be grouped under one manager and cost center—for example, station and facilities maintenance and power and signal maintenance—the managers helped clarify how many employees worked on what specific functions.

SAN DIEGO TROLLEY, INC.

In the late 1970s, the responsibility to construct and operate San Diego's new light rail system was given to a new agency. SDTI has since operated the country's only single-mode light rail service with all necessary support staff under its direct control. [Some of these support services, such as human resources, will be transferred this year (2005) to the umbrella Metropolitan Transit Development Board as a consolidation of such functions among the board's subsidiary transit providers.] After initial deliberation, the agency decided to develop and operate the light rail system itself.

The organizational structure of SDTI has rail operations and maintenance under the Vice-President of Operations. This position oversees the superintendents of LRV maintenance, wayside maintenance, and operations (Figure 4). Facilities maintenance, fare equipment maintenance, and stores management are under the Vice-President of Administration, who oversees the Facilities Manager, the Revenue Manager, and the Stores Manager (among others). The following discussion of SDTI is based on its FY2005 budget and board-approved staff levels.

LRV Maintenance

There are three job descriptions in the area of LRV maintenance: Electromechanic–LRV, Lineman–LRV, and Assistant Lineman–LRV. According to the job descriptions, all three positions are virtually identical except for the entry qualifications and training responsibilities. A candidate for the assistant lineman position must (among other things) qualify for the SDTI Assistant Lineman Apprenticeship Program and be able to lift 50 lb unaided. Electromechanics and linemen must have already passed the SDTI Apprenticeship Program or have previous education and experience equal to or greater than the program; the 50-lb lifting requirement is absent. Linemen must help train assistant linemen, and electromechanics must help train the other two. SDTI's organization shows an assistant superintendent in both the LRV maintenance and MOW areas.

There are a total of 80 LRV maintainer positions, 10 management (salaried) positions, and 2 clerical positions in LRV maintenance. The system has a total fleet of 123 LRVs, 83 of which are used during peak periods. SDTI operated 7,079,000 revenue vehicle-miles in 2004.

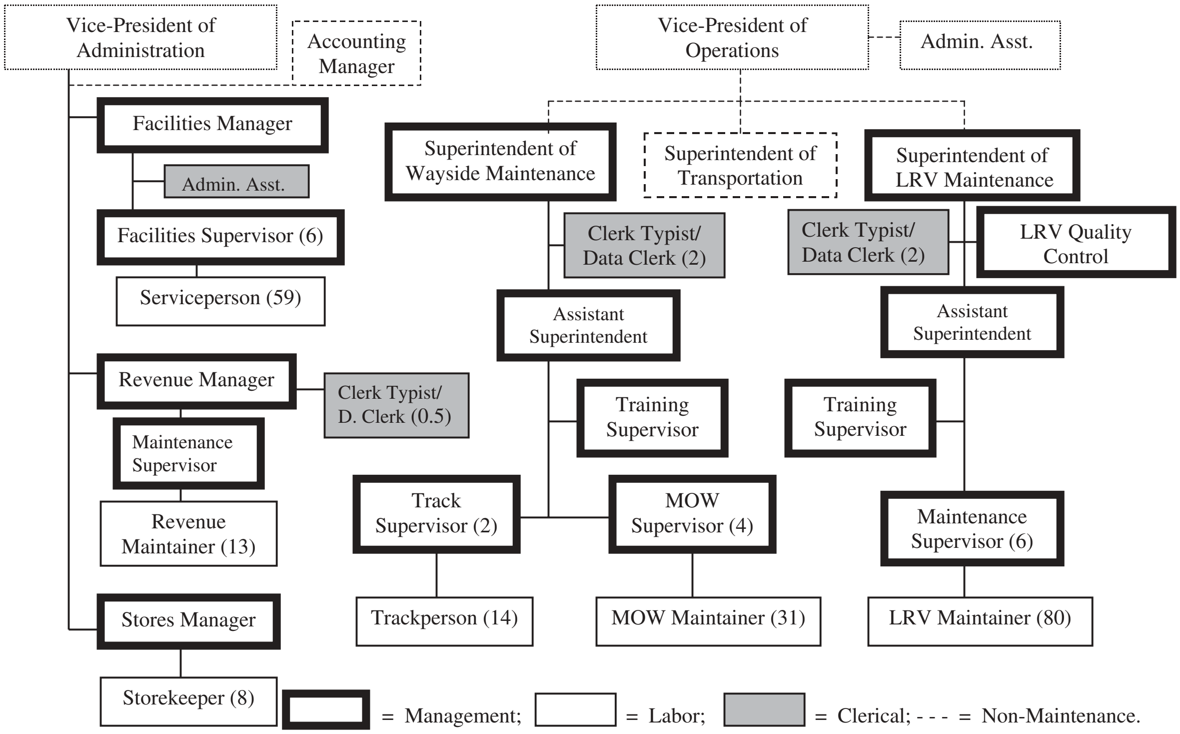

FIGURE 4 San Diego Trolley, Inc., structure of LRT maintenance organization.

MOW Maintenance

Light rail maintenance organizations often have the MOW functions under one manager. SDTI is an example of this organizational structure. The Superintendent of Wayside Maintenance handles all the administrative duties for the working functional groups under him. Three management and two clerical positions perform these administrative duties.

The classification and job description pattern described above for LRV maintenance is identical for power and signal maintenance. The personnel classification for those working in these areas is MOW maintainers. The three relevant job descriptions are: Electromechanic–MOW, Lineman–MOW, and Assistant Lineman–MOW. The qualifications for these positions reflect those for the LRV positions down to the 50-lb lifting requirement. Although this unit's training course has the very same name as the LRV maintainer's, the program for MOW positions is tailored to substation, catenary, signal, and communication equipment repair.

Although all MOW maintainers can work in any of the four functional areas, in general at any given time, SDTI managers estimate that approximately half of the 31-person force works on traction power and catenary repair and half on signals and communication repair. The four management positions in the group are divided in the same proportion.

Weather typically does not play a major role in SDTI's MOW. Strong winds during certain times of the year can affect crossing gates (as many as 27 have broken in one day.) Moreover, the little annual precipitation that San Diego does receive can come in a few intense storms and cause occasional track washouts.

Track maintenance has its own group composed of 2 track supervisors, considered management positions within SDTI, and 14 track "servicepersons" (maintainers). Track maintainers do not yet have an established apprenticeship program, although SDTI just (FY2005) approved a Training Supervisor—Wayside position for both the power/signal and the track maintenance areas. The MOW maintenance group maintains 96.6 mi of track.

Facilities and Station Maintenance

This maintenance group and the next two discussed here come under SDTI's Vice-President for Administration (see Figure 4). Reporting to this vice-president are a manager of facilities, six facilities supervisors, and an administrative assistant. The unit has one labor position—serviceperson—of which there are 59. The manager estimates that 1 FTE supervisor and 10 serviceperson FTEs work repairing SDTI's nonstation facilities, such as the yards and shops complex. The remaining 5 supervisors and 49 servicepersons clean and repair the system's 49 stations.

Fare Equipment Maintenance

This maintenance function is also found under the Vice-President for Administration, specifically under the Revenue

Manager. The position manages the operating aspects of revenues as well as the maintenance of fare equipment. Under the Maintenance Supervisor there are 13 revenue maintainers responsible for maintaining and repairing the system's 119 TVMs.

Stores Management

Every maintenance department must have some place to store and retrieve parts needed in the repair of the system's rolling stock and fixed facilities. San Diego's stores group is under the Vice-President of Administration, although it is housed in the yards and shops complex. The Stores Manager oversees eight storekeepers.

Manpower Ratios

Table 5 summarizes the maintenance staff of San Diego Trolley by functional area. There are 240 total FTEs. This is 2.5 (vehicle and nonvehicle) maintenance employees per track-mile, 2.9 employees per VOMS, or 3.2 employees per 100,000 revenue car-miles. Of the 240, 38% are involved in the maintenance of the LRVs, 7% are involved with fare equipment maintenance, and 4% with stores management. Of the remaining employees, 23% maintain the wayside, 23% the stations, and 3% other fixed facilities.

Table 6 tabulates the productivity indices of SDTI's maintenance staff. The first row arrays the ratio of management staff to labor (nonclerical) staff. It shows a range of between 5.2 and 8.9. The overall average is 5.9. For the main areas of vehicle and wayside maintenance the range is between 7 and 8. The next rows calculate the number of employees needed to maintain a unit of the system, be it a vehicle, a mile of trackway, or a fare vending machine.

Outside Contracting

Table 7 shows what percentage of nonutility costs were expected to be contracted out by SDTI in its FY2005 budget year as a percentage of total costs (wage and nonwage) for each maintenance function. The highest percentage of outside contracts is in the track maintenance area and probably reflects the relatively low level of track maintenance planned this particular year. Of the outside contracts let for track maintenance, 71% is planned for track maintenance services and contracted track crews. The greatest dollar amount of outside services is in LRV maintenance. Fully 63% of those costs are for interior car cleaning services, most of the rest is for contracted accident repair and vandalism repairs. Of the contracted services in the signal and communications area 80% is for crossing gate maintenance and repair. In all, SDTI plans to expend 11.3% of its maintenance expenditures on outside services.

UTAH TRANSIT AUTHORITY

Salt Lake City's light rail system opened in 1999. It is one of the newest LRT systems in the country, with only the Hudson–Bergen (2002), Houston (2003), and Minneapolis (2004) systems opening since then. It operates in a climate of large temperature extremes, but with little annual rain or snow.

UTA, a multimodal service provider, is organized into three business units. One supplies the actual bus and rail transit services and another business services support for the operating units, with a third not directly involved with operations. The Rail Services Business Unit has both rail operations and rail maintenance under a Rail Service General Manager (Figure 5). The rail maintenance functions are separated into an LRV maintenance group and an MOW maintenance group. Rail station maintenance is managed out of UTA's Support

TABLE 5
SAN DIEGO TROLLEY'S LRT MAINTENANCE STAFF (FTEs)

			Maintenance of Way							
Category	Total	LRV Maintenance	Administration	Track Maintenance	Traction Power and Catenary Maintenance	Signals and Commun. Maintenance	Station Maintenance	Facilities Maintenance	Fare Collection Equipment Maintenance	Stores Management
Managers	29.5	10	3	2	2	2	5.5	1.5	2.5	1
Labor	205	80	0	14	15	16	49	10	13	8
Clerical	5.5	2	2	0	0	0	0.5	0.5	0.5	0
Total	240	92	5	16	17	18	55	12	16	9

TABLE 6
SAN DIEGO TROLLEY'S STAFF PRODUCTIVITY INDICATORS

			Maintenance of Way							
Productivity Index (employees = managers + labor + clerical)	Units Involved	LRV Maintenance	Administration	Track Maintenance	Traction Power and Catenary Maintenance	Signals and Communication Maintenance	Station Maintenance	Facilities Maintenance	Fare Collection Equipment Maintenance	Stores Management
Workers per Manager	N/A	8	N/A	7	7.5	8	8.9	6.7	5.2	8
Employees per LRV (peak)	83	1.11								0.11
Employees per LRV (fleet)	123	0.75								0.07
Employees per Track-Mile	96.6		0.05	0.17	0.18	0.19				
Employees per Station	49						1.12			
Employees per Maintenance Facility	2							6.00		
Employees per TVM	119								0.13	

Notes: N/A = not available; TVM = ticket vending machine.

Services Business Unit under the Manager of Facilities Maintenance. This position is responsible for maintaining all of UTA's facilities (except for the rail yards and shops), including rail stations and bus stops.

There are two levels of management, a minimal number of maintenance worker classifications, and no clerical staff. UTA's structure does not have an assistant superintendent level of management.

LRV Maintenance

In its first 5 years the LRT fleet increased from 10 vehicles to 46. To keep up with this growth the LRV maintenance unit has had to increase its staff accordingly. The training of the staff is done through courses at local community colleges, in-house classes, on-the-job training, and training by equipment vendors. Electromechanics must pass tests that demonstrate their proficiency. LRV maintainers are encouraged to work in diverse areas and typically do. Some workers gravitate to a particular specialty.

TABLE 7
SAN DIEGO'S OUTSIDE CONTRACTING COSTS
TO TOTAL MAINTENANCE COSTS

Maintenance Area	Percent of Total Costs
LRV Maintenance	14.1
Track Maintenance	16.6
Traction Power Maintenance	3.3
Signals and Communication Maintenance	9.8
Station Maintenance	14.4
Facilities Maintenance	13.4
Fare Equipment Maintenance	3.8

Positions are usually filled internally, typically from the rail services employees. Were it not for the growth of the fleet, there would not be many job openings: only one electromechanic has left in 5 years. Fully 67% of LRV maintenance employees have a perfect attendance record, and only 1% to 2% is absent more that a few times a year. The FMLA has not had any effect. UTA's rail fleet is 46 vehicles, of which 39 are typically needed during peak periods. UTA operated 2,355,000 revenue vehicle-miles in 2004.

MOW Maintenance

Two groups are on the organization chart—MOW and facilities—but in practice there are three: track, line, and facilities maintenance. Each unit has two related job classifications. In track maintenance there are the Rail Maintenance Supervisor and Rail Maintenance Workers (six positions). In facilities maintenance there are the Facilities Maintenance Manager and the Class A Mechanics (three positions).

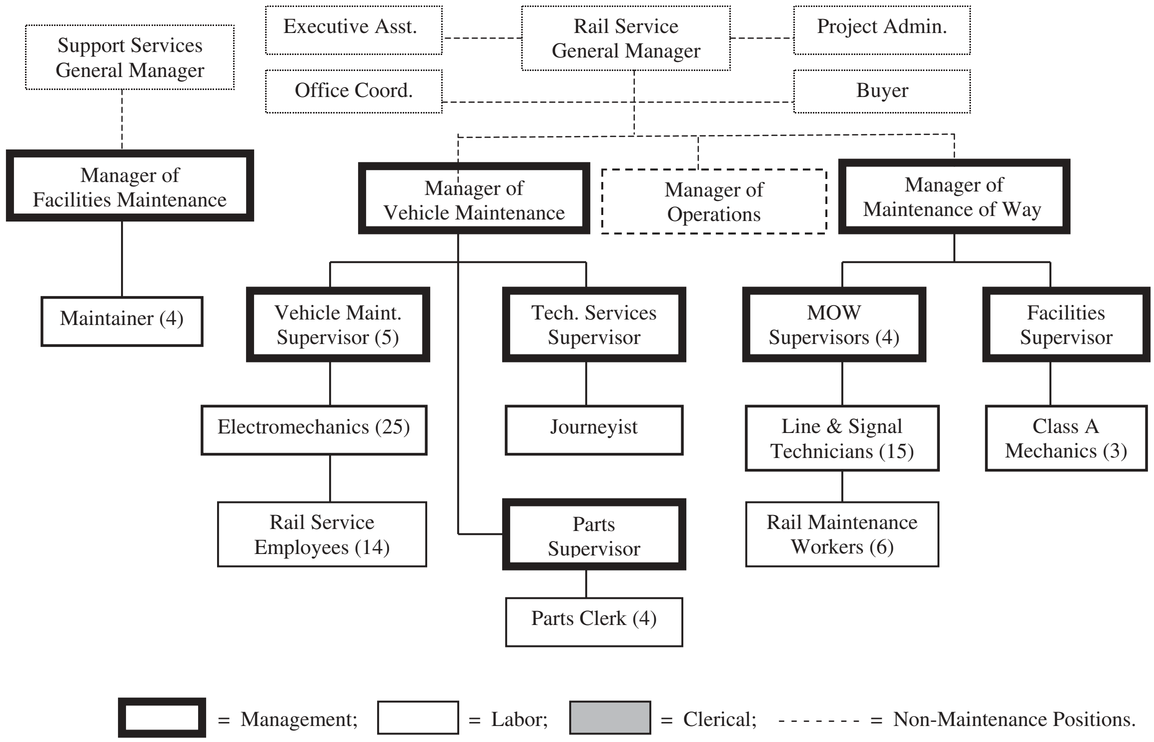

FIGURE 5 Salt Lake City UTA's structure of LRT maintenance organization.

For line maintenance there is the MOW Supervisor (3 positions) and the Line and Signal Technician (15 positions). These 18 people maintain and repair substations, overhead catenary, signals, grade-crossing gates, and TVMs. Each supervisor and technician is expected to work on any of these and does. An estimate of the percentage of time the three supervisors spend on these areas is 10% on substations, 20% on TVMs, and 70% on signals and crossing gates. The technicians divide their time a little differently. There is now a program to replace all catenary hangers and two technicians have been assigned that work. Another 1.3 FTEs maintain the substations, which require little attention. The remaining 11.7 FTEs spend 75% of their time on the signal system and 25% on TVM repairs. To work on the signal system a technician has to complete two levels of Union Pacific's signal school and have a period of on-the-job training.

It is believed that costs are low because the system was designed and built with good drainage and track structure (130-lb rail with concrete ties), the staff tries to get ahead of any problems (such as with the hanger replacement program), and the system is relatively new. Weather is not seen as a major maintenance factor. As with LRV maintenance, staff turnover is low: in 5 years only one line technician and one supervisor have left. The system operates more than 38.9 track-miles and has 65 grade crossings. It has one yard and shop complex and 62 TVMs.

Station Maintenance

Station maintenance is done by the Support Services Business Unit by a group of employees who maintain all bus garages and other UTA facilities, bus stops, and rail stations. (The MOW workers also do light maintenance at stations, such as touch-up painting and changing light bulbs.) The manager in charge estimates that station maintenance takes 1.65 management FTEs and 4 labor FTEs. The station maintenance crews are supported by the outside contracts described here.

UTA has no clerical staff assigned to any maintenance functions. An office coordinator assigned to the Rail Service General Manager spends approximately 10% of that position's time doing data entry; however, the remainder of the data is entered by the supervisors or technicians themselves. This results in only valuable data being kept; those data are useable and to the point.

Manpower Ratios

Table 8 arrays UTA's rail maintenance staff by function. The total number of rail maintenance staff is 86.7 FTEs, for an average of 2.23 employees per track-mile, 2.9 employees per VOMS, or 3.7 employees per 100,000 revenue vehicle-miles. Fifty-three percent of the staff works in LRV maintenance, 26% in MOW (track, power, signals) maintenance, approxi-

TABLE 8
SALT LAKE CITY'S LRT MAINTENANCE STAFF (FTEs)

			Maintenance of Way							
Category	Total	LRV Maintenance	Administration	Track Maintenance	Traction Power and Catenary Maintenance	Signals and Commun. Maintenance	Facilities Maintenance	Fare Collection Equipment Maintenance	Station Maintenance	Stores Management
Managers	14.7	6	1	1	0.3	2.1	1	0.6	1.7	1
Labor	72	40	0	6	3.3	8.8	3	2.9	4	4
Clerical	0	0	0	0	0	0	0	0	0	0
Total	86.7	46	1	7	3.6	10.9	4	3.5	5.7	5

mately 7% in station maintenance, with the rest in facilities and TVM maintenance and stores management.

Table 9 calculates the system maintenance productivity factors. Overall there is one management employee for every 4.9 maintainers.

Outside Contracting

UTA contracts out a substantial amount of station maintenance work, as indicated in Table 10. The county of Salt Lake, through an interagency agreement, performs periodic sweeping of parking lots, snow removal at parking lots, landscaping

TABLE 9
SALT LAKE CITY'S STAFF PRODUCTIVITY INDICATORS

			Maintenance of Way							
Productivity Index (employees = managers + labor + clerical)	Units Involved	LRV Maintenance	Administration	Track Maintenance	Traction Power and Catenary Maintenance	Signals and Communication Maintenance	Facilities Maintenance	Fare Collection Equipment Maintenance	Station Maintenance	Stores Management
Workers per Manager	N/A	6.7	N/A	6	11	4.2	3	4.8	2.4	4
Employees per LRV (peak)	39	1.18								0.11
Employees per LRV (fleet)	46	1.00								0.07
Employees per Track-Mile	38.9		0.03	0.18	0.09	0.28				
Employees per Station	23								0.25	
Employees per Maintenance Facility	1						4.00			
Employees per TVM	62							0.06		

Notes: N/A = not available; TVM = ticket vending machine.

TABLE 10
SALT LAKE CITY'S OUTSIDE MAINTENANCE COSTS TO TOTAL MAINTENANCE COSTS

Maintenance Area	Percent of Total Costs
LRV Maintenance	0.1%
Track Maintenance	
Traction Power Maintenance	
Signals and Commun. Maintenance	4.1%
Facilities Maintenance	
Fare Equipment Maintenance Station	
Maintenance	about 50%

maintenance, and asphalt repairs. The contract is for $300,000 per year. Station glass and vandalism repairs are done through an outside contract; approximately $100,000 was spent on these repairs in 2004. A private contractor also provides station cleaning services through a $75,000 per year contract, and other outside contractors perform another $25,000 per year on station repairs that are beyond the abilities of the UTA's crews to handle. The LRV maintenance area has no outsourced repair work to speak of, and the MOW area contracts out functions such as track inspection, geometry car services, and weed control.

TRI-COUNTY METROPOLITAN TRANSPORTATION DISTRICT OF OREGON

This system was inaugurated in 1986 and has expanded to its present 3-line, 62-station, 82-mi network.

TriMet's organization structure has all rail maintenance functions under a Director, Rail Maintenance (Figure 6). There are four basic groups under this position: LRV maintenance (done at two facilities), MOW maintenance, maintenance administration, and stores management. Although TriMet allocates the expenses of the director and his support administrative staff to both LRV and MOW maintenance, for this study that unit will be kept separate. The discussion that follows is based on FY2004 staff and actual year-end expenditures.

LRV Maintenance

Portland has had three generations of LRVs. It established its own vehicle engineering group to manage vehicle upgrades. This group is considered to be a very necessary unit to address vehicle design and overhaul issues and to help train LRV mechanics.

TriMet started with a single yard and shop complex (Ruby Junction) in 1986, but added a second, smaller yard and shop

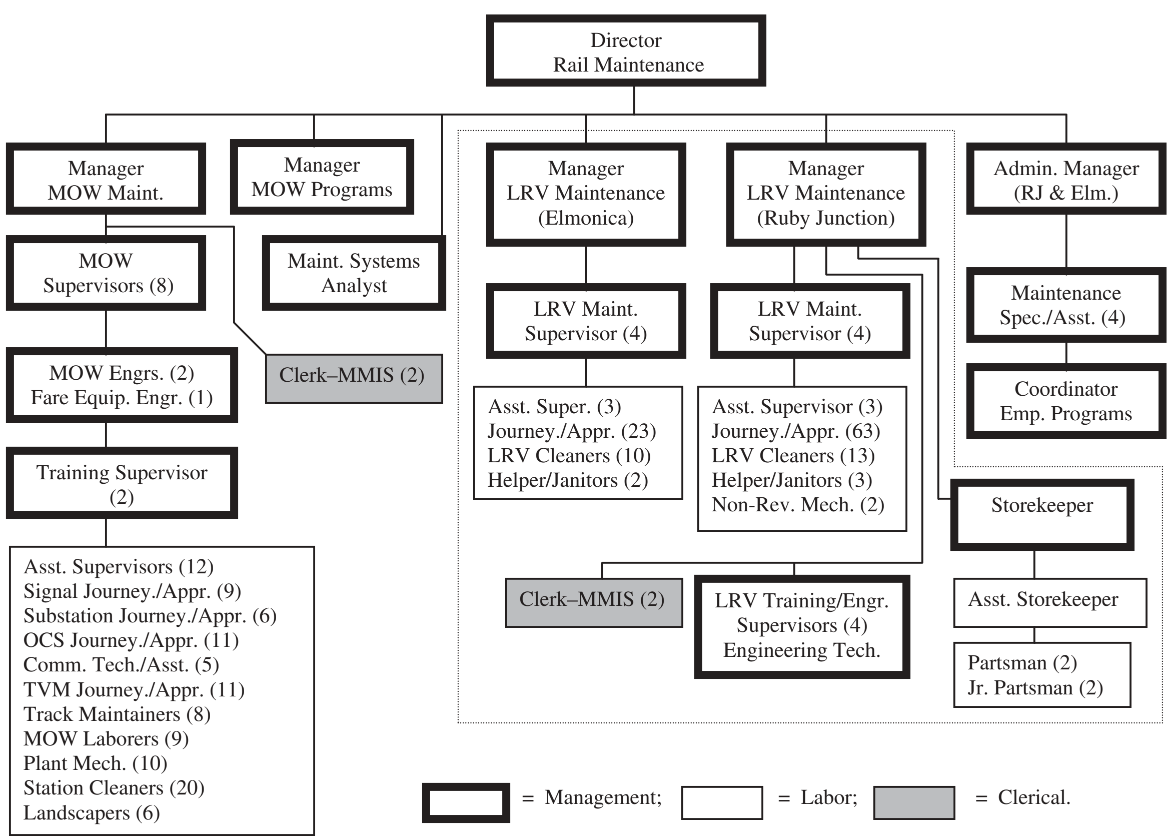

FIGURE 6 Portland TriMet's structure of LRT maintenance organization. (Some job titles have been modified for clarity.) MMIS = maintenance management information system.

facility on the opposite side of downtown (Elmonica) when it extended its Blue Line to the Hillsboro area. The main facility remains at Ruby Junction, where all major LRV repair work is done.

TriMet has one job classification for LRV maintainers: LRV Maintenance Technician. There are two levels involved, an apprentice and a journeyman. A journeyman can work alone and sign off on inspections. Both the apprentice and journeyman can work on any aspect of LRV maintenance and repair within the limits of his or her experience and training. To make sure there will be enough trained LRV journeymen available when needed, LRV maintenance managers start a group of prequalified candidates on a 30-month training program every year or so. These groups have included from 10 to 19 students. Experience shows that 30% of the students do not complete the program. In the 7 years since 1998, 37 journeymen and apprentices have left the agency (an average of 7% each year) and 54 apprentices have been trained in 6 groups (76 started the training). This training–replacement cycle has kept a pool of well-trained apprentices available for advancement.

Early on, TriMet LRV maintenance contracted out a lot more of its maintenance, but now contracts an ever-decreasing amount owing to union requests and a desire for better quality control. The LRV maintenance group currently has 119 LRV maintenance technicians, 15 management positions, and 2 clerks. TriMet does its own LRV cleaning in-house and has a staff of 23 for this function. It has a fleet of 95 vehicles, of which 83 are used during peak service. TriMet operated 6,775,000 revenue vehicle-miles in 2004.

MOW Maintenance

As seen in Figure 6, all MOW maintenance personnel report to a single Manager, MOW Maintenance. Under this manager are eight MOW supervisors, one each for track/laborers, substations, overhead catenary, signals, communications, cleaners/landscapers, facilities, and fare equipment. Under them are 12 assistant supervisors: two each for track, substations, overhead catenary, and cleaners/landscapers; one each for signals, communication, facilities, and fare equipment. These eight functional groups are supported by an engineering and training staff of five. The entire MOW group has 98 MOW maintainers, 14 management staff, and 3 clerical staff. The system has 88.6 track-miles, with 62 stations and 2 yards and shops facilities.

It is clear that TriMet emphasizes training. As with the LRV maintenance group, the MOW maintenance group has its own training staff. There are five functional areas that require different applicant prerequisites: traction power substation maintainers, overhead traction electrification maintainers, rail communication system technician, signal maintainer, track maintenance technician, and fare equipment/LRT lift technician. As with LRV maintainers, the advancement path is apprentice to journeyman, although advancement is typically within one's selected function.

Although Portland's climate has a fair amount of annual precipitation, it is spread out over the year and weather is not seen as a maintenance problem. The two MOW problems noted were downtown curb rail, especially in the fall with leaves, and overhead catenary section insulators.

Stores Management

The Storekeeper reports directly to the Director of Rail Maintenance, but is physically located at the Ruby Junction yard. There are two assistant storekeepers and four partsmen in this group. The reason for the two assistants reflects the need to service the two yards.

Manpower Ratios

Table 11 summarizes TriMet's maintenance staffing by function. The entire LRT maintenance staff equals 279 FTEs. This is 3.4 maintenance employees (vehicle and nonvehicle) per track-mile, 4.8 employees per VOMS, or 4.9 employees per 100,000 revenue car-miles. Of the 279 FTEs, 40 are management, 5 are clerical, and 234 are maintainers; this is an overall maintainer-to-manager ratio of 5.9. Forty-nine percent are involved in LRV maintenance, 25% in MOW maintenance, 13% in station maintenance, and 3% in facilities maintenance. Overall division management (3%), fare equipment (5%), and stores management (2%) make up the remaining 10%.

Table 12 calculates TriMet's maintenance productivity indicators. There is one management position for every eight LRV maintainers. For MOW, the ratio of management positions to MOW maintainers ranges from 8 to 34. One would expect there to be more management presence in the signal and communications area because of its critical importance and technical nature, and perhaps the opposite explains the high ratio for station maintenance.

Contracting Out Maintenance Tasks

Portland undertakes a limited amount of contracting out in the area of LRV maintenance except for the laundry services contract. Table 13 shows what percent of nonutility costs were contracted out in FY2004 as a percentage of total costs (wage and nonwage) for each maintenance functional area. Of note is the percentage of signal and communications maintenance and repair that was contracted out. The next highest percent was for track maintenance, and those contracts involved rail grinding (37%), rail maintenance (39%), equipment rental (14%), and bridge repair (10%). Elevator repair constituted 58% of outside contracts in station maintenance, and almost all the outside contracts in the facilities maintenance area were

TABLE 11
PORTLAND'S LRT MAINTENANCE STAFF (FTEs)

				Maintenance of Way							
Category	Total	Maintenance Administration	LRV Maintenance	Administration	Track Maintenance	Traction Power and Catenary Maintenance	Signals and Communication Maintenance	Station Maintenance	Facilities Maintenance	Fare Collection/LRT Lift Equipment Maintenance	Stores Management
Managers	40	8	15	7	1	2	2	1	1	2	1
Labor	234	0	119	0	19	21	16	34	8	12	5
Clerical	5	0	2	3	0	0	0	0	0	0	0
Total	279	8	136	10	20	23	18	35	9	14	6

for building repairs. In all, 4.6% of the maintenance expenditures were for outside services.

GREATER CLEVELAND REGIONAL TRANSPORTATION AUTHORITY

RTA is a multimodal (bus, rapid transit, light rail, and Community Response Transit) system that has served the city of Cleveland and all other cities in Cayahoga County since 1975. The light rail network operates over 30 mi; the rapid transit lines over 38 mi. The light rail line was opened originally in 1920 and was substantially rebuilt in the mid-1980s. Major rail track rehabilitation is currently underway. It is one of the country's oldest, continuously operating light rail systems. RTA is unique in the light rail industry in that the light rail and rapid transit systems are both maintained by the same

TABLE 12
PORTLAND'S STAFF PRODUCTIVITY INDICATORS

			Maintenance of Way							
Productivity Index (employees = managers + labor + clerical)	Units Involved	LRV Maintenance	Administration	Track Maintenance	Traction Power and Catenary Maintenance	Signals and Communication Maintenance	Station Maintenance	Facilities Maintenance	Fare Collection/LRT Lift Equipment Maintenance	Stores Management
Workers per Manager	N/A	8	N/A	19	10.5	8	34	8	6	5
Employees per LRV (peak)	83	1.64								0.07
Employees per LRV (fleet)	95	1.43								0.06
Employees per Track-Mile	88.6		0.11	0.23	0.26	0.20				
Employees per Station	62						0.56			
Employees per Maintenance Facility	2							4.50		
Employees per TVM	183								0.08	

Notes: N/A = not available; TVM = ticket vending machines.

TABLE 13
PORTLAND TRIMET'S OUTSIDE CONTRACTING COSTS TO TOTAL MAINTENANCE COSTS

Maintenance Area	Percent of Total Costs
LRV Maintenance	0.07
Track Maintenance	18.4
Traction Power Maintenance	4.2
Signals and Communication Maintenance	20.6
Station Maintenance	7.0
Facilities Maintenance	7.8
Fare Equipment Maintenance	0

staff, and both types of railcars are maintained in the same yard and shops. Until 1984 there were three shops (two for rapid transit and one for LRT); however, expectations of efficiencies owing to centralization and a capitally funded modernization program resulted in the three shops being combined into one new shop. The shop's major function is being a running repair facility for rapid transit and light rail cars with a small amount of heavy repair and overhaul work being performed as staffing, budget, and time permit.

The RTA system runs mostly single-car trains in peak as well as base service, and runs some two-car trains in the peak periods owing to ridership requirements. Of the 48 LRVs purchased when the light rail line was rehabilitated, 16 are used during peak service; of the 60 rapid transit cars available, 22 are used during peak service. The eight football games and about three special events each year at the Cleveland Browns Stadium require approximately 32 LRVs to handle the crowds. The result of this fleet size versus peak period needs is that one-third of the fleet is stored for a month at a time, and then another one-third replaces them the next month. This is called "inventory rotation" by RTA staff. Through inventory rotation all the railcars are maintained to be able to function acceptably and safely. Cleveland operated 954,000 revenue vehicle-miles in 2004.

The organizational structure of the RTA's Rail District has all operating and maintenance functions under a District Director. There are four managers under this director overseeing transportation, rail equipment maintenance, power and way maintenance, and facilities maintenance, as shown in Figure 7. The responsibilities of the maintenance managers are typical for LRT systems, except that they include both LRV and rapid transit cars.

The functional manager estimated that 60% of his employees worked on LRT maintenance and the remaining 40% on rapid transit.

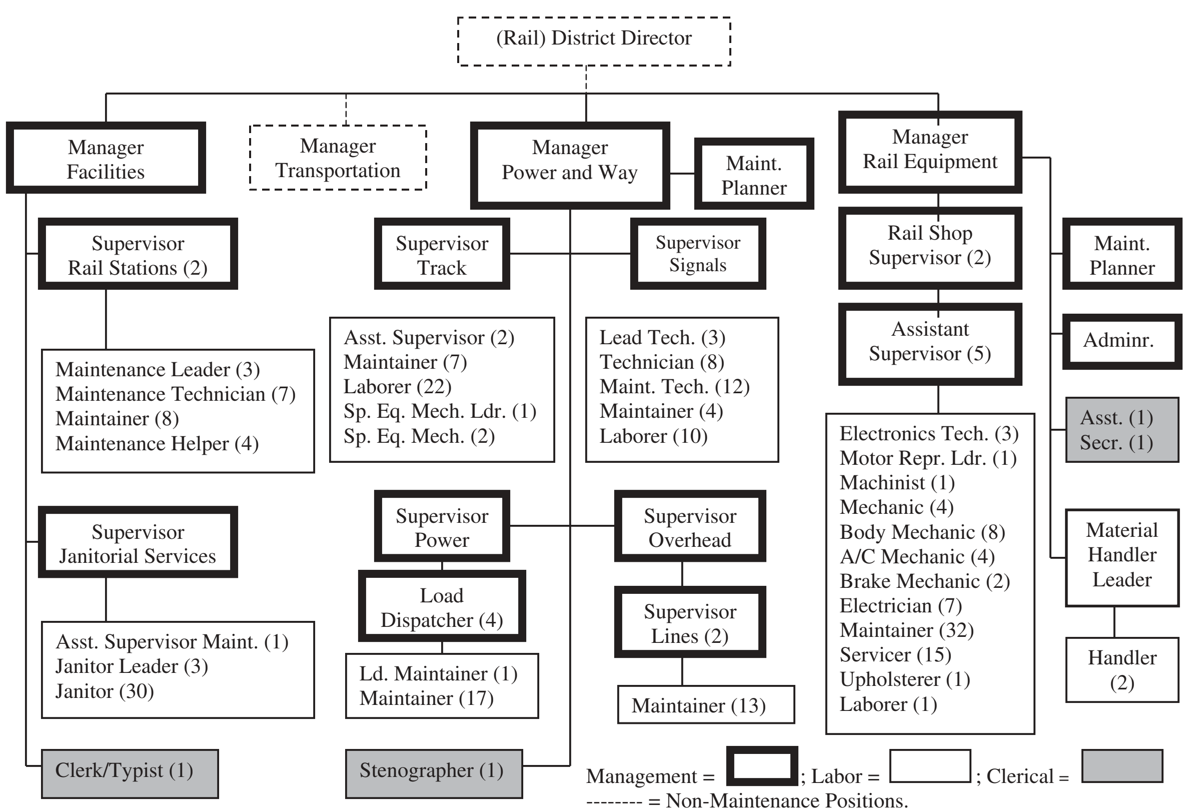

FIGURE 7 Cleveland RTA's structure of rail maintenance organization (light rail and rapid transit).

LRV Maintenance

Owing to budget constraints, over the last 10 years the number of LRV and rapid transit maintenance positions has dropped from 115 to 86—from 104 to 86 in the last 3 years alone—and an additional 9 positions remain frozen and unfilled. Inventory rotation lessens somewhat the LRV maintenance load. RTA has received federal funding to perform a mid-life overhaul of 34 of the LRVs. This project is primarily contracted out, with some work being performed by RTA maintenance staff. The contractor has begun to deliver rebuilt cars. Maintenance of the LRV fleet is a challenge owing to the fleet's age, parts availability, escalation of costs, and available staff to do this work, in addition to the required maintenance of the rapid transit fleet.

The organization chart lists a number of specialized LRV maintenance positions; there are 14 job descriptions below the management levels in the LRV maintenance area. Labor agreements allow workers to shift between maintenance jobs as they advance. This increases efficiency and allows for a certain amount of cross-training. However, once a maintenance worker achieves the highest level, he/she is restricted from working out of position. For example, a worker can work primarily as an electrician for many years, but will also work, gain experience, and train in other areas as needed. However, if he or she applies for and is selected as a senior-level brake mechanic, from then on this individual cannot do an electrician's tasks.

Many of RTA's LRV mechanics were hired in the 1970s and are close to having the 30 years of service required for full retirement.

Based on RTA's experience with railcar maintenance, maintaining the LRV takes twice as much work as maintaining the rapid transit cars.

Rail stores are also housed within the LRV maintenance group. The 2005 approved budgeted positions consist of four parts handlers, one leader and three clerks.

MOW Maintenance

The MOW department includes four main functional units—track, power, overhead, and signals and communications—headed by a manager with support staff. The employees in each of these functional units are specialists, and there are several job descriptions within each unit. There are three to five designated MOW positions reflecting the more formal levels of advancement. Most training is developed and provided in-house by power and way staff as part of normal duties. The LRT train control and signal system is maintained by the signal department. Current LRV train control consists of cab-signaled and computerized central train control territory, automated braking system territory, dark (no signal) territory with some station protection signals, and dark territory.

The MOW manager indicated that the percentage of time MOW staff worked on light rail could be fairly approximated by the track-miles of LRT to the total LRT and rapid transit track-miles. The LRT system has 33 track-miles, or 44% of RTA's total track-miles.

RTA has a crew of three charged with operating and maintaining special equipment and the nonrevenue vehicles used by the division.

TABLE 14
CLEVELAND'S LRT MAINTENANCE STAFF (FTEs)

			Maintenance of Way							
Category	Total	LRV Maintenance	Administration	Track Maintenance	Traction Power and Catenary Maintenance	Signals and Communication Maintenance	Station Maintenance	Facilities Maintenance	Fare Collection/LRT Lift Equipment Maintenance	Stores Management
Managers	8.8	3.1	0.9	0.45	1.75	0.45	1.8	0.2	N/A	0.1
Labor	127	51.2	0.4	15	13.6	16.3	22	6.5	N/A	2
Clerical	1.8	1.3	0	0	0	0	0.4	0.1	N/A	0
Total	137.6	55.6	1.3	15.4	15.4	16.8	24.2	6.8	N/A	2.1

Note: N/A = not available.

TABLE 15
CLEVELAND'S STAFF PRODUCTIVITY INDICATORS

			Maintenance of Way							
Productivity Index (employees = managers + labor + clerical)	Units Involved	LRV Maintenance	Administration	Track Maintenance	Traction Power and Catenary Maintenance	Signals and Communication Maintenance	Station Maintenance	Facilities Maintenance	Fare Collection/LRT Lift Equipment Maintenance	Stores Management
Workers per Manager	N/A	17.9	N/A	30.2*	8.8	36.2*	12.2	32.5*	N/A	20*
Employees per LRV (peak)	16	3.48								0.13
Employees per LRV (fleet)	48	1.16								0.04
Employees per Track-Mile	33.0		0.40	0.47	0.47	0.51				
Employees per Station	39						0.62			
Employees per Maintenance Facility	1							6.80		
Employees per TVM	13								N/A	

Notes: N/A = not available; TVM = ticket vending machine.
*These functional areas have less than one manager FTE overseeing the maintainers. This results in manager-to-employee ratios greater than the number of employees performing the work.

TABLE 16
TOTAL MAINTENANCE STAFF STATISTICS
FOR CASE STUDY CITIES

	San Diego	Salt Lake City	Portland (Oregon)	Cleveland
Total Maintenance Employees	240	87	279	138
Employees per VOMS	2.9	2.9	4.8	9.2
Employees per 100,000 Revenue Vehicle-Miles	3.2	3.7	4.9	14.7
Employees per Track-Mile	2.5	2.23	3.4	4.2
Percent of Staff in:				
LRV maintenance	38%	53%	49%	40%
Maintenance of way	23%	25%	25%	36%
Station maintenance	23%	7%	13%	17%
Facilities maintenance	5%	5%	3%	5%
TVM maintenance	7%	4%	5%	N/A
Stores management	4%	6%	2%	2%
Overall maintenance administration	0%	0%	3%	0%

Notes: N/A = not available; VOMS = vehicle operated in maximum service; TVM = ticket vending machine.

Station and Facilities Maintenance

These functions are both managed by the Manager, Facilities. Under him are two supervisors for stations and facilities, and a supervisor for janitorial services. The manager estimates that approximately 80% of staff time is allocated to station cleaning and maintenance, 20% to the maintenance of the yards and shops. These crews spend 50% of their time on LRT and 50% on rapid transit stations. RTA has 34 light rail stations and one rail maintenance facility.

Fare Equipment Maintenance

RTA collects fares on its light rail system using the train operator and a farebox. Outbound it collects fares on entering; inbound it collects fares on exiting. There are 13 TVMs, which are all at rapid transit stations. For this reason, the summary of staff that follows indicates "not applicable" in the fare equipment column.

Manpower Ratios

Table 14 summarizes RTA's maintenance staff by functional area. There are approximately 137.6 FTEs performing light rail maintenance. This is 4.2 total maintenance employees per track-mile, 9.2 employees per VOMS, or 14.7 employees per 100,000 revenue car-miles. Of that number, 8.8 FTEs are

TABLE 17
COMPARISON OF MAINTENANCE EMPLOYEES WITH ORGANIZATIONAL STRUCTURE AND JOB POSITIONS

System	Maintenance Employees per Track-Mile	Maintenance Employees per VOMS	Maintenance Employees per 100,000 Revenue Car-Miles	Simplicity of Organizational Structure	Number of Maintenance Positions in Organization
Salt Lake City	2.2	2.9	3.7	Simple	16
San Diego	2.3	2.9	3.2	Simple	23
Portland	3.4	4.8	4.9	Moderate	37
Cleveland	4.2	9.2	14.7	Moderately complex	53

Note: VOMS = vehicle operated in maximum service.

TABLE 18
MAINTAINER-TO-MANAGER RATIOS OF SOME LRT SYSTEMS

LRT System	LRV Maintenance	Track Maintenance	Traction Power and Overhead Maintenance	Signal and Communication Maintenance	Station Maintenance	Facilities Maintenance	Fare Collection Equipment Maintenance	Stores Management
Case Study Cities								
Cleveland's RTA	17.9	30.2	8.8	36.2	12.2	32.5	N/A	20
Portland's TriMet	8	19	10.5	8	34	8	6	5
Salt Lake City's UTA	6.7	6	11	4.2	2.4	3	4.8	4
San Diego's SDTI	8	7	7.5	8	8.9	6.7	5.2	8
Other Cities								
Buffalo's NFTA	6.25	4	6.5	20	24	24	*	—
Dallas' DART	5.7	3.5	6.1	2.6	3.1	1.25	5.9	—
Philadelphia's SEPTA	8.4	6	5	2.5	8	4	5	—
Possible Common Range	6–8	5–7	6–10	4–8	8–12	4–8	5–6	4–7

Notes: When the number of manager FTEs assigned is less than one, the number of maintainers shown will be greater than the actual number. N/A = not available.
*Buffalo's survey response indicated no manager position for this function.

TABLE 19
PRODUCTIVITY INDICATORS OF SOME LRT SYSTEMS

Productivity Indicator (employees = managers + labor + clerical)	LRV Maintenance Employees per Peak LRV	LRV Maintenance Employees per Fleet LRV	MOW Administrative Staff per Track-Mile	Track Maintenance Employees per Track-Mile	TP and OCS Maintenance Employees per Track-Mile	S & C Maintenance Employees per Track-Mile	Station Maintenance Employees per Station	Facilities Maintenance Employees per Yard	TVM Maintenance Employees per TVM	Stores Staff per Fleet LRV
Case Study Cities										
Cleveland's RTA	3.48	1.16	0.04	0.47	0.47	0.51	0.62	6.80	N/A	0.04
Portland's TriMet	1.64	1.43	0.11	0.23	0.26	0.20	0.56	4.50	0.08	0.06
Salt Lake City's UTA	1.18	1.00	0.03	0.18	0.09	0.28	0.25	4.00	0.06	0.07
San Diego's SDTI	1.11	0.75	0.05	0.17	0.18	0.19	1.12	6.00	0.13	0.07
Other Cities										
Buffalo's NFTA	1.26	1.07	0.32	0.40	1.21	1.69	1.56		0.12	—
Dallas' DART	1.37	1.21	0.03	0.38	0.39	0.52	0.95	7.18	0.17	—
Philadelphia's SEPTA	6.57	5.35	0.35	0.82	0.28	0.33	3.75	16.67	N/A	—
Possible Common Range	1.2–1.6	1.0–1.5	0.03–0.05	0.17–0.38	0.18–0.40	0.20–0.40	0.4–1.0	4–7	0.06–013	0.06–0.07

Notes: N/A = not available; TP = traction power; OCS = overhead catenary systems; S & C = signal and communications; TVM = ticket vending machine.

management, 127 are maintainers, and 1.8 are clerical for an overall maintainer-to-manager ratio of 14.4. Of the 138 total FTEs, 41% perform LRV maintenance, 58% are in MOW maintenance, and the remaining 1+% are MOW management or stores management.

Table 15 calculates RTA's maintenance productivity indicators. The number of peak period LRVs increases the number of employees per vehicle ratio; the number of total railcars makes this corresponding ratio low.

Contracting Out Maintenance Tasks

For several reasons, the number of outsourced contracts for parts of LRT maintenance could not be calculated for the RTA. Before this year, RTA did not keep separate line item accounts for LRT and rapid transit maintenance expenditures.

SUMMARY OF CASE STUDIES

This section of the report compares the case study cities. It introduces similar data from Buffalo's Niagara Frontier Transit Authority (NFTA), the Dallas Area Rapid Transit Authority (DART), and Philadelphia's Southeastern Pennsylvania Transit Authority (SEPTA) that became available (see Appendix C). The summary tables include a "common range" that new and existing systems may use when considering maintenance staff issues. The common ranges are not numerical averages of the data displayed, but are suggestions based on the systems reviewed.

Table 16 arrays some basic maintenance staffing statistics of the four case study cities. Its top section indicates the total number of maintenance employees (management, maintainers, and clerks) per unit of measure. The lower portion shows the percentage of total maintenance staff involved in each functional area. All systems have the largest percentage of their staffs in rail vehicle maintenance. Except for Cleveland, the systems have one-quarter of their staffs in the MOW (MOW administration, track, power, and signals). Cleveland's percentage may be higher because of its climate. The widest range is in station maintenance (7% to 23% of staff), most probably related to the amount of station maintenance done through contracts. Salt Lake City, for example, does a lot of its station maintenance through the county's public works department. Portland's organizational structure is the only one that has staff doing overall administration for the rail maintenance department. It consumes 3% of its staff and another 3% for MOW administration. The other systems have administrative positions for their MOW maintenance units and in two cases for their

TABLE 20
MAINTAINER-TO-CLERK RATIOS
OF SOME LRT SYSTEMS

System	Maintainer-to-Clerk Ratio
Cleveland's RTA	80:1
Portland's TriMet	47:1
Salt Lake City's UTA	72:0*
San Diego's SDTI	37:1
Buffalo's NFTA	18:1
Dallas' DART	27:1
Philadelphia's SEPTA	34:1

*Salt Lake City LRT system has no clerks.

LRV maintenance units as well, but no overall administrative staff positions.

Table 17 compares the employees per unit of measure for each agency with the agencies' organizational structures and the number of job classifications. The table was developed by looking at each system's organization chart (see Figures 4–7). Salt Lake City's organizational structure has two management levels. Salt Lake City also has few separately titled positions in its organization chart. San Diego, Portland, and Cleveland show increasing organizational complexity and number of maintenance positions.

Table 18 compares the maintainer-to-manager ratios by maintenance function. All systems include in the manager category supervisors not represented by a bargaining unit. (In cases where an agency has less than one manager FTE in a maintenance function the resulting maintainer-to-manager ratio will indicate more maintainers than the system actually has.)

Almost all the systems have maintainer-to-manager ratios of between six and eight for LRV maintenance. This ratio also seems fairly representative for MOW maintenance. Perhaps because station maintenance is a less skilled function, the station maintainer-to-manager ratios are slightly higher; that is, fewer supervisors direct more workers. The ratio drops back into the four-to-seven range for facilities maintenance, fare machine maintenance, and stores handling.

Table 19 arrays the staff productivity indicators by case study agencies. Three other agencies (NFTA, DART, and SEPTA) provided staff data that are incorporated in the table. For LRV maintenance, two productivity indicators are shown: LRV maintainers per vehicle operated in maximum service and LRV maintainers per vehicle available. The second indicator is added because many systems have higher spare ratios that may unfairly skew their productivity indicators. The common range seems to be 1.2–1.6 maintainers per available railcar.

The productivity indicators in the MOW area are stated in terms of employees per track-mile. There is, of course, no ideal number with which all properties can be compared; however, approximately 0.2 to 0.4 track maintainer, power (substation and overhead) maintainer, and signal (signal and communications) maintainer for every track-mile in the system appears to be a common scope.

The clerk-to-maintainer ratios of the seven properties are shown in Table 20. The Salt Lake City system has none at all; supervisors and technicians at this agency enter their own data. A common number seems to be one clerk/secretary/assistant for each 35 maintainers or less.

CHAPTER FIVE

CONCLUSIONS

Each light rail transit (LRT) agency operates in a unique environment. For this reason, it is difficult to guide a light rail agency to an optimal maintenance staff. However, it is natural for managers to be curious as to how they are doing; to compare themselves with industry norms. This synthesis of industry practice offers some information in this area.

It does not appear that the number of vehicle maintenance staff has any direct relationship to vehicle type, average vehicle age, or rate of revenue service failures. Nor does climate or even age of system infrastructure allow for any firm conclusions on the optimal maintenance of way (MOW) staff levels. There are too many factors involved to be able to isolate any one as causal, and too few LRT systems to perform a meaningful regression analysis. There are also nonquantifiable factors involved, including budget constraints, collective bargaining agreements, worker morale, and/or management philosophies. *It is not possible to extract from published system statistics clear guidance on maintenance staffing*.

Certain indicators are used by most agencies as benchmarks. The most widely used is the "number of revenue system failures" for light rail vehicle maintenance. However, accurate information on this indicator is lacking owing to the varied definitions in use. National Transit Database statistics show reported annual revenue system mechanical failures ranging from zero to several thousand. This range appears to be large. *Because of its importance to maintenance managers, the industry could benefit from a consistent definition of "revenue system failures."*

For MOW maintenance the benchmark most used is "cost per track-mile." Comparing the cost to maintain a track-mile among U.S. cities, however, is difficult, because each system is in a different cost-of-living area. Spare parts, on the other hand, are often purchased on the national or even global market. *Some useful non-cost indicator of MOW maintenance performance could be selected by the industry as its standard benchmark.*

The need for and efficient use of common spare parts was noted by many transit systems. Although this is difficult to achieve given the number of railcar vendors in the market, *the industry might want to select and standardize key components with high failure/replacement rates.*

The industry does not use part-time employees: only 4 of the LRT industry's approximately 3,400 maintenance workers are designated as such. Moreover, there is universal agreement that it is less expensive to implement overtime than to hire additional staff.

The case studies were helpful in providing information on maintenance staff levels. The four systems chosen for review were organized somewhat differently and had different numbers of maintenance positions. *Overall productivity as measured by total maintenance employees per unit of common measure (track-mile, peak vehicle, or car-mile) appears to be better with simpler organizations and fewer job classifications.*

There also seems to be a fairly consistent range of maintainers-to-manager ratios across the industry. These vary somewhat by the technical nature of the maintenance function. For example, most agencies reviewed had more managers to maintainers in the signal and communications functional area than in any other. This makes sense given the critical nature of this subsystem. *The study results could be used to confirm whether a staffing plan has a reasonable blend of managers and maintainers.*

The staff productivity indicators—employees per unit of measure—vary as well among the agencies surveyed. It was nevertheless possible to recognize a possible common range. Light rail transit systems can use these common staffing ranges (summarized in chapter four) as a check on reasonableness.

APPENDIX A

Analysis of National Transit Database Data on Vehicle Maintenance

TABLE A1
ANNUAL LRV MAINTENANCE TASK-HOURS BY AVERAGE AGE OF FLEET (Vehicle-Related Data Sorted by Average Age of Fleet)

Name	Climate Type	Vehicles Operated in Maximum Service	Vehicles Available for Maximum Service	Average Age of Fleet (in Years)	Total Revenue System Mechanical Failures	Vehicle Maintenance Task-Hours	Vehicle Maintenance FTEs (+PT)	Vehicle Maintenance Task-Hours per VOMS	FTEs per VOMS	Vehicle Maintenance Task-Hours per Vehicle Available	FTEs per Vehicle Available
Salt Lake City	3	30	33	2.4	24	103,420	60.0	3,447.3	2.0	3,133.9	1.8
Denver	3	41	49	4.0	0	76,222	40.2	1,859.1	1.0	1,555.6	0.8
Dallas	3	56	91	4.6	39	253,382	157 (+2)	4,524.7	2.8	2,784.4	1.7
St. Louis	4	49	65	5.1	297	84,850	44.0	1,731.6	0.9	1,305.4	0.7
Baltimore	4	49	53	8.3	96	83,677	56.0	1,707.7	1.1	1,578.8	1.1
Los Angeles	1	69	102	8.8	2,489	384,591	173.0	5,573.8	2.5	3,770.5	1.7
Portland	3	58	72	10.6	444	264,402	156.0	4,558.7	2.7	3,672.3	2.2
San Diego	1	83	123	12.2	193	151,586	73.0	1,826.3	0.9	1,232.4	0.6
Sacramento	2	32	36	13.9	40	160,524	84.0	5,016.4	2.6	4,459.0	2.3
Hudson-Bergen	4	15	29	14.6		N/A	N/A	N/A	N/A	N/A	N/A
Santa Clara	1	41	66	15.6	98	191,360	92.0	4,667.3	2.2	2,899.4	1.4
Pittsburgh	4	47	55	17.0	187	202,317	99.7	4,304.6	2.1	3,678.5	1.8
Buffalo	4	23	27	18.0	45	41,530	22.3	1,805.7	1.0	1,538.1	0.8
San Francisco	1	128	167	18.5	2,276	776,564	373.3	6,066.9	2.9	4,650.1	2.2
Boston	4	155	199	19.1	1,190	345,280	166 (+1)	2,227.6	1.1	1,735.1	0.8
Cleveland	4	15	48	21.0	81	72,031	40.0	4,802.1	2.7	1,500.6	0.8
Philadelphia	4	117	141	21.6	676	317,939	163.0	2,717.4	1.4	2,254.9	1.2
Newark	4	12	16	34.5	45	136,146	65.0	11,345.5	5.4	8,509.1	4.1

FTEs = full-time equivalents; PT = part-time equivalents; VOMS = vehicle in maximum service; N/A = not available.
Source: National Transit Database.

TABLE A2
ANNUAL LRV MAINTENANCE TASK-HOURS PER EMPLOYEE (Indicators Related to Vehicle Maintenance Sorted by Task-Hours per Employee)

Name	Vehicles Operated in Maximum Service (VOMS)	Vehicles Available for Maximum Service	Vehicle Maintenance FTEs (+PT)	Labor Hours for Inspection and Maintenance	Labor Hours for Vehicle Maintenance and Inspection per Vehicle Maintenance Employee	Vehicle Maintenance Task-Hours	Vehicle Maintenance Task-Hours per Vehicle Maintenance Employee	Vehicle Maintenance Task-Hours per VOMS	Vehicle Maintenance Task-Hours per Vehicle Available
Baltimore	49	53	56	71,705	1,280	83,677	1,494	1,708	1,579
Dallas	56	91	157 (+2)	66,095	416	253,382	1,594	4,525	2,784
Portland	58	72	156	83,291	534	264,402	1,695	4,559	3,672
Salt Lake City	30	33	60	73,736	1,229	103,420	1,724	3,447	3,134
Cleveland	15	48	40	53,192	1,330	72,031	1,801	4,802	1,501
Buffalo	23	27	22.3	18,860	846	41,530	1,862	1,806	1,538
Denver	41	49	40.2	72,576	1,805	76,222	1,896	1,859	1,556
Sacramento	32	36	84	181,947	2,166	160,524	1,911	5,016	4,459
St. Louis	44	65	44	68,600	1,559	84,850	1,928	1,732	1,305
Philadelphia	117	141	163	198,386	1,217	317,939	1,951	2,717	2,255
Pittsburgh	47	55	99.7	181,967	1,825	202,317	2,029	4,305	3,678
Boston	155	199	166 (+1)	297,500	1,781	345,280	2,068	2,228	1,735
San Diego	83	123	73	145,497	1,993	151,586	2,077	1,826	1,232
Santa Clara	41	66	92	224,183	2,437	191,360	2,080	4,667	2,899
San Francisco	128	167	373.3	466,788	1,250	776,564	2,080	6,067	4,650
Newark	12	16	65	18,860	290	136,146	2,095	11,346	8,509
Los Angeles	69	102	173	167,924	971	384,591	2,223	5,574	3,771

FTEs = full-time equivalents; PT = part-time equivalents; VOMS = vehicle operated in maximum service.
Source: National Transit Database.

TABLE A3
ANNUAL LRV MAINTENANCE TASK-HOURS PER VEHICLE OPERATING IN MAXIMUM SERVICE (Indicators Related to Vehicle Maintenance Sorted by Annual Task-Hours per Peak Vehicle)

Name	Vehicles Operated in Maximum Service (VOMS)	Vehicles Available for Maximum Service	Vehicle Maintenance FTEs (+PT)	Labor Hours for Inspection and Maintenance	Labor Hours for Veh. Maint. and Inspection per Veh. Maint. Employee	Vehicle Maintenance Task-Hours	Vehicle Maintenance Task-Hours per Vehicle Maintenance Employee	Vehicle Maintenance Task-Hours per VOMS	Vehicle Maintenance Task-Hours per Vehicle Available
San Diego	83	123	73	145,497	1,993	151,586	2,077	1,826	1,232
St. Louis	44	65	44	68,600	1,559	84,850	1,928	1,732	1,305
Cleveland	15	48	40	53,192	1,330	72,031	1,801	4,802	1,501
Buffalo	23	27	22.3	18,860	846	41,530	1,862	1,806	1,538
Denver	41	49	40.2	72,576	1,805	76,222	1,896	1,859	1,556
Baltimore	49	53	56	71,705	1,280	83,677	1,494	1,708	1,579
Boston	155	199	166 (+1)	297,500	1,781	345,280	2,068	2,228	1,735
Philadelphia	117	141	163	198,386	1,217	317,939	1,951	2,717	2,255
Dallas	56	91	157 (+2)	66,095	416	253,382	1,594	4,525	2,784
Santa Clara	41	66	92	224,183	2,437	191,360	2,080	4,667	2,899
Salt Lake City	30	33	60	73,736	1,229	103,420	1,724	3,447	3,134
Portland	58	72	156	83,291	534	264,402	1,695	4,559	3,672
Pittsburgh	47	55	99.7	181,967	1,825	202,317	2,029	4,305	3,678
Los Angeles	69	102	173	167,924	971	384,591	2,223	5,574	3,771
Sacramento	32	36	84	181,947	2,166	160,524	1,911	5,016	4,459
San Francisco	128	167	373.3	466,788	1,250	776,564	2,080	6,067	4,650
Newark	12	16	65	18,860	290	136,146	2,095	11,346	8,509

FTEs = full-time equivalents; PT = part-time equivalents; VOMS = vehicle operated in maximum service.
Source: National Transit Database.

APPENDIX B

Results of Light Rail Transit Maintenance Staffing Questionnaire

TBD = to be determined; IP = in progress; * = see comments in Appendix C

AGENCY PHILOSOPHY, POLICIES, AND STANDARDS REGARDING LRT SYSTEM MAINTENANCE

1. How did you determine your initial level of staffing? (Rank up to three)

Question	Buffalo	Cleveland	Dallas	Denver	Houston	Philadelphia	Pittsburgh	Portland	Salt Lake City	San Diego	San Francisco	Responses	Percentage	Weighted Responses	Weighted Percentages
a. system too old to know							1	1			1	3	30%	9	20%
b. used recommendation of consultants	1	1	1		3					2		3	30%	12	27%
c. required to conform to existing union agreements	2					1						1	10%	5	11%
d. used historic formulas			2		1	2						1	10%	7	16%
e. purposefully overstaffed to provide trained staff for next extension						3						0	0%	1	2%
f. wanted to emphasize outsourcing opportunities										2		0	0%	2	4%
g. other:			3*	1*	2*				1*			2	20%	9	20%
												10	100%	45	100%

2. What factors determine your present level of staffing? (Rank up to three)

Question	Buffalo	Cleveland	Dallas	Denver	Houston	Philadelphia	Pittsburgh	Portland	Salt Lake City	San Diego	San Francisco	Responses	Percentage	Weighted Responses	Weighted Percentages
a. requirements to conform to union agreements	3											0	0%	1	2%
b. historic formulas						1	3			2		1	10%	6	10%
c. experience with manpower availability	1	3	2	2		2	2	1		2		2	20%	17	29%
d. policies on service quality (e.g., cleanliness, reliability, etc.)	2		1	1	2		1	2	1		1	5	50%	21	36%
e. low spare ratio or excessive vehicle maintenance needs		2	3		1	3		3				1	10%	8	14%
f. high worker turnover												0	0%	0	0%
g. budget limitations		1								2		1	10%	5	8%
h. other:						3*						0	0%	1	2%
												10	100%	59	100%

3a. Was contracting out most or all maintenance functions ever considered?

Question	Buffalo	Cleveland	Dallas	Denver	Houston	Philadelphia	Pittsburgh	Portland	Salt Lake City	San Diego	San Francisco	Responses	Percentage
yes			X		X	X				X		4	36%
no	X	X		X			X	X	X		X	7	64%
												11	100%

3b. If not, what might have been the reasons? (Choose one)

Question	Buffalo	Cleveland	Dallas	Denver	Houston	Philadelphia	Pittsburgh	Portland	Salt Lake City	San Diego	San Francisco	Responses	Percentage
a. never thought of it												0	0%
b. no precedence in industry												0	0%
c. existing union agreements precluded it		X				X		X				3	33%
d. 13C requirements/approvals were felt to be too difficult												0	0%
e. wanted direct control of maint. quality				X				X				2	22%
f. other:	X*						X*		X*		X*	4	44%
												9	100%

Question		Buffalo	Cleveland	Dallas	Denver	Houston	Philadelphia	Pittsburgh	Portland	Salt Lake City	San Diego	San Francisco	Responses	Percentage
4.	**Does your agency have established maintenance standards/goals for…?**													
a.	exterior cleanliness of railcars	X	X			X			X		X	X	6	19%
b.	interior cleanliness of railcars	X	X			X			X		X	X	6	19%
c.	maintenance standards	X		X		X	X		X	X	X	X	8	28%
d.	component standards												0	0%
e.	time allowed before TVM repair	X	X										2	6%
f.	time allowed before lamp replacement in public areas of stations	X				X							2	6%
g.	time allowed before crossing-gate repair					X				X		X	3	10%
h.	others:			X*				X*		X		X	4	13%
													31	100%
5.	**Do you feel the maint. goals/standards are adequately and consistently monitored?**													
a.	yes	X		X	X	X	X		X	X	X	X	9	90%
b.	no												0	0%
c.	inconsistently monitored		X									*	1	10%
													10	100%
6.	**Do you feel "benchmarking" your performance is useful or realistic as a way to improve?**													
a.	yes, we benchmark quite a bit					X					X		2	18%
b.	we benchmark in certain areas		X				X		X	X			4	36%
c.	no, there are too many differences between properties to benchmark	X		X	X			X				X	5	45%
													11	100%
7.	**If you benchmark, what performance indicators do you benchmark against? (Choose any that apply)**													
a.	maintenance expenses per revenue vehicle-mile		X			X			X	X	X		5	28%
b.	maintenance expenses per track-mile										X		1	6%
c.	miles between revenue vehicle failures	X	X			X	X	X	X		X		7	39%
d.	maintenance labor hours per vehicle					X					X		2	11%
e.	annual revenue-miles per employee								X	X	X		3	17%
f.	MTBF for TVMs and escalators (if any) or other equipment												0	0%
g.	others:												0	0%
													18	100%
8.	**Would ridership allow single-car trains during midday or evening?**													
a.	yes	X	X	X	X	X		X			X	X	8	80%
b.	no								X	X			2	20%
													10	56%
9a.	**If the answer above is yes, do you run single-car trains?**													
a.	yes	X	X	X		X		X			X	X	7	88%
b.	no				X								1	13%
													8	100%

MTBF = mean time between failures (Question 7f).

Question	Buffalo	Cleveland	Dallas	Denver	Houston	Philadelphia	Pittsburgh	Portland	Salt Lake City	San Diego	San Francisco		Responses	Percentage	Weighted Responses	Weighted Percentages
9b. If the answer is no, what are reasons you don't?																
a. agency policy on level of seating off-peak													0	0%		
b. reliability concerns of single-car operation													0	0%		
c. inefficient to drop and add railcars								X					1	33%		
d. no midday storage for dropped railcars													0	0%		
e. too many riders				X					X*				2	67%		
													3	100%		
LABOR CONSIDERATIONS																
10. What factors most affect your overall maintenance productivity? (Rank three)																
a. labor agreements								1		2			1	10%	5	8%
b. quality of service policies	2		1		2			3	1				2	20%	11	19%
c. high manpower turnover rates		1								2			1	10%	5	8%
d. age of equipment	1	2		2			3		2	2			1	10%	12	20%
e. design flaws of equipment or facilities					1	2			3				1	10%	6	10%
f. new FLMA and other "external" labor requirements							2						0	0%	2	3%
g. expanding union benefits and time-off rules in agency/union contracts	3						1	2					1	10%	6	10%
h. weather uncertainties		3				3							0	0%	2	3%
I. other:			2*	1*	3*	1*					1*		3	30%	12	20%
													10	100%	61	100%
11. In what areas do labor agreements limit you the most? (Rank up to two)																
a. they don't really limit me			1	1	1				1	2			4	36%	14	29%
b. requires too much extra manpower for work required								2					0	0%	2	4%
c. difficult to manage vacation, sick days and unscheduled time-off	1									1			2	18%	6	12%
d. hinders cross-training		2				2	2						0	0%	6	12%
e. makes it difficult to advance good workers	2	1		2		1	1	1			1		5	45%	19	39%
f. other:											2*		0	0%	2	4%
													11	100%	49	100%
12. Do you have any incentive programs to encourage better work attendance?																
a. money bonus for good attendance over a certain period	X		X	X	X						X		5	45%		
b. competition between maintenance facilities	X												1	9%		
c. more training based on better attendance													0	0%		
d. other:		X*				X*	X*		X*		X*		5	45%		
													11	100%		
13. Would an "extra board" pool help meet swings in manpower availability?																
a. yes	X					X				X	X		4	40%		
b. no		X		X				X	X				4	40%		
c. we use an extra board arrangment			X				X*	*					2	20%		
													10	100%		
14. Do you find it more cost-effective to allow overtime than to hire new staff positions?																
a. yes	X	X	X	X	X	X	X	X	X	X	X		11	100%		
b. no													0	0%		
c. have not figured this out													0	0%		
													11	100%		

Question	Buffalo	Cleveland	Dallas	Denver	Houston	Philadelphia	Pittsburgh	Portland	Salt Lake City	San Diego	San Francisco		Responses	Percentage
15. Do maint. employees receive training to be proficient, advance or move laterally?														
a. they receive training as needed for position only	X			X	X			X		X			5	24%
b. they receive training for advancement	X		X			X			X				4	19%
c. they receive cross-training where allowed			X		X	X				X			4	19%
d. they receive some training, but mainly learn on the job	X	X					X			X	X		5	24%
e. money for training is below needs		X				X				X*			3	14%
													21	100%
VEHICLE MAINTENANCE														
16. What is the single main indicator of good vehicle maintenance?														
a. percentage of fleet available for revenue service each day	X	X	X		X				X				5	45%
b. number of annual revenue service breakdowns				X		X	X	X		X	X		6	55%
c. good ratings in passenger surveys or low complaint levels													0	0%
d. other:													0	0%
													11	100%
17. When specifying your light rail vehicle, was there a conscious effort to buy something that already was in service or being built for another agency?														
a. no, railcar was designed specifically for my agency		X	X		X	X	X	X			X		7	54%
b. an effort was made to specify a railcar already being produced	X			X					X	X			4	31%
c. an effort was made to specify common components				X		X							2	15%
													13	100%
18. Do you feel that design flaws were adequately addressed in subsequent vehicle orders or by the manufacturer under the warrantee requirements?														
a. yes	X		X		X	X			X				5	50%
b. no		X						X		X			3	30%
c. somewhat		X								X*			2	20%
													10	100%
19. Based on your experience, would it lower maintenance costs if more parts were common among operators?														
a. yes	X	X	X	X	X		X	X	X	X	X		10	91%
b. no						X							1	9%
c. slightly													0	0%
													11	100%
20. Do you experience serious delays in receiving needed spare parts?														
a. yes	X	X	X	X	X	X	X	X	X	X	X		11	100%
b. no													0	0%
													11	100%
21. Do you work with other properties to procure common parts, provide common parts, or exchange maint. experience about common parts?														
a. yes		X		X	X			X	X	X			6	55%
b. no	X		X			X	X				X		5	45%
													11	100%
22a. Have work standards been developed for tasks involved in *preventive* maintenance?														
a. yes	IP		X		X				X	X			4	40%
b. no		X		X		X	X	X			X		6	60%
													10	100%

Question		Buffalo	Cleveland	Dallas	Denver	Houston	Philadelphia	Pittsburgh	Portland	Salt Lake City	San Diego	San Francisco	Responses	Percentage
22b. If yes, are these being adequately monitored?														
a.	yes			X		X		X					3	75%
b.	no										X		1	25%
													4	100%
23a. Do you have work standards for tasks involved in *repairs* (e.g., man-hours/task)?														
a.	yes												0	0%
b.	no	X	X		X		X	X	X	X	X	X	9	82%
c.	not possible due to nature of work			X		X							2	18%
													11	100%
23b. If yes, are these being adequately monitored?														
a.	yes												0	0%
b.	no												0	0%
													0	0%
24. Given the daily demands of the operating department, do you feel you mainly perform "corrective" maintenance or "preventative" maintenance?														
a.	preventative		X		X	X							3	27%
b.	corrective										X		1	9%
c.	good balance	X		X			X	X	X	X		X	7	64%
													11	100%
25. What vehicle maintenance functions are outsourced?														
a.	daily cleaning			X							X		2	8%
b.	upholstery repair						X			X	X	X	4	15%
c.	body/collision repair										X		1	4%
d.	window repair												0	0%
e.	brake system repair/overhaul					X		X		X			3	12%
f.	wheel truing												0	0%
g.	graffiti removal			X									1	4%
h.	motor repair/overhaul	X	X	X	X	TBD		X	X	X	X		8	31%
I.	electronics repair			X		TBD		X		X			3	12%
j.	passenger car fleet servicing/repair												0	0%
k.	maint. equipment servicing/repair		X							X		X	3	12%
l.	other:			*		*		*			X		1	4%
													26	100%
WAYSIDE, TRACK, AND TRACTION POWER (GUIDEWAY) MAINTENANCE														
26. What is the single main indicator of good guideway maintenance?														
a.	ride quality determined by periodic testing	X					X	X			X	X	5	45%
b.	total of all annual revenue service delays due to track conditions		X	X	X	X			X				5	45%
c.	good ratings in passenger surveys or low complaint levels												0	0%
d.	other:								*	X*			1	9%
													11	100%
27. Which maintenance functions are to some extent covered by collective bargaining agreements? (Choose any that apply)														
a.	track maintenance		X		X		X	X	X	X	X	X	8	21%
b.	traction power/catenary system		X		X		X	X	X	X	X	X	8	21%
c.	communication system		X				X	X	X	X		X	6	16%
d.	signal system		X		X		X	X	X	X	X	X	8	21%
e.	ticket vending machines		X		X		X	N/A	X	X	X	X	7	18%
f.	others:			*							X*		1	3%
													38	100%

QUESTION	Buffalo	Cleveland	Dallas	Denver	Houston	Philadelphia	Pittsburgh	Portland	Salt Lake City	San Diego	San Francisco	Responses	Percentage
28. What guideway maintenance functions are outsourced?													
a. landscaping		X	X		X	X	X		X			6	43%
b. wayside trash removal		X	X									2	14%
c. graffiti removal			X									1	7%
d. traction power repairs									X			1	7%
e. communication repairs		X					X			X		3	21%
f. signal system repairs		X										1	7%
g. other:			*				*					0	0%
												14	100%
29. Do any other agencies help with system maintenance?													
a. no	X		X	X			X		X	X		6	55%
b. station cleaning												0	0%
c. parking lot cleaning		X										1	9%
d. street repair between mixed-flow tracks					X	X		X		X		4	36%
e. other:											*	0	0%
												11	100%
FACILITIES AND EQUIPMENT MAINTENANCE													
30. What is the single main indicator of good facility maintenance?													
a. cleanliness						X		X	X			3	25%
b. low number of things needed to be fixed based on periodic inspections		X	X	X	X		X			X	X	7	58%
c. good ratings in passenger surveys or low complaint levels (stations)	X											1	8%
d. other:					*			*	X		*	1	8%
												12	100%
31. Does your system have CCTV coverage of stations or an Automatic Train Information System?													
a. CCTV	X	X			X		X	X		X	X	7	50%
b. ATIS	IP				X			X	X	X	X	5	36%
c. other similar:		X	X*									2	14%
												14	100%
32. Do these features require more than expected maintenance?													
a. yes		X			X				X	X	X	5	56%
b. no	X	X			*		X	X				4	44%
												9	100%
33. What facilities and equipment maintenance functions are outsourced?													
Daily cleaning of:													
a. transportation building/lockers			X		X				X			3	10%
b. maintenance offices/lockers			X		X				X			3	10%
c. stations			X		X				X			3	10%
d. elevator/escalator repair	X	X	X		X		X	X		X	X	8	27%
e. TVM repair												0	0%
f. servicing/repair of motor pool			X						X	X		3	10%
g. servicing/repair of maint. vehicles		X	X						X	X		4	13%
h. repair of buildings and stations		X	X		X		X					4	13%
I. other:		X*	X*		*		*					2	7%
												30	100%

APPENDIX C

Written Comments to Survey Questionnaire

Agency Philosophy, Policies, and Standards Regarding LRT System Maintenance

1. How did you determine your initial level of staffing? (Rank up to three)

- Salt Lake City: Developed in-house based on system characteristics and other's experience.
- Dallas: High level of training anticipated to establish minimum level of technical knowledge to maintain initial system requirements.
- Denver: Used other transit systems' information.
- Houston: Surveyed other properties and took into consideration their current experience.

2. What factors determine your present level of staffing? (Rank up to three)

- Cleveland added budget as a factor.
- San Diego added budgetary limitations as a factor.
- Houston added time availability to work on system and vehicles during nonrevenue time.

3b. If not, what might have been the reasons? (Choose one)

- Buffalo: Separate agreement in beginning with union.
- Pittsburgh did not know reasons.
- Salt Lake City: Too expensive; concern about service quality.
- San Francisco: Local labor climate and past practices.

4. Does your agency have established maintenance standards/goals for…?

- Dallas: Mean time between systems failures (e.g., traction power and signals).
- Pittsburgh noted that board-approved standards are not known.

5. Do you feel the maintenance goals/standards your agency establishes are adequately and consistently monitored?

- San Francisco: Voter-mandated service standards reported on quarterly.

9b. If the answer to Question 9 is no what are reasons you do not?

- Salt Lake City noted it has too many riders to run single-car trains off-peak.

Labor Considerations

10. What factors most affect your overall maintenance productivity? (Rank three)

- Dallas: Consistency of operating to established service plans and parts availability.
- Denver: Special services.
- Houston: Current staff experience.
- Philadelphia: Stream of parts or repair components.
- San Francisco: Budget shortfall and original equipment manufacturer supply time lines.

11. In what areas do labor agreements limit you the most? (Rank up to two)

- San Francisco: It is difficult to select best qualified candidate; seniority dictates assignment location and shift.

12. Do you have any incentive programs to encourage better work attendance?

- Cleveland: Uses a General Manager TEAM Incentive Bonus based on performance and meeting or exceeding standards.
- Philadelphia: "Earned" day off for good attendance.
- Pittsburgh: Accumulated sick time toward pension.
- Salt Lake City: Ad hoc awards for performance including attendance.
- San Francisco: Dollars for mean distance between failures, availability, and on-time performance.

13. Would an "extra board" pool help meet swings in manpower availability?

- Pittsburgh added that it uses extra board for relief assignments.
- Portland added that it uses an extra board arrangement.

15. Do maintenance employees receive adequate training to be proficient, advance, or move laterally?

- San Diego emphasized that money for training is below needs.

Vehicle Maintenance

18. Do you feel that design flaws were adequately addressed in subsequent vehicle orders or by the manufacturer under the warrantee requirements?

- Pittsburgh noted that it was too soon to tell.

19. Based on your experience, would it lower maintenance costs if more parts were common among operators?

- San Diego emphasized that there would definitely be lower costs if more parts were common.

22a. Have work standards been developed for each task involved in *preventive* maintenance (e.g., man-hours/task)?

- Buffalo noted that developing APTA standards are now in process.

25. What vehicle maintenance functions are done in-house vs. outsourced?

- Dallas noted that graffiti removal and motor repair are done both in-house and through outside vendors.
- Houston: It does brake repair in-house; brake overhaul to be determined.
- Pittsburgh: It does 70% of brake repair/overhaul in-house, the rest is outsourced, and it does 75% of electronic repair in-house.

Wayside, Track, and Traction Power (Guideway) Maintenance

26. In your opinion, what is the single main indicator of good guideway maintenance?

- Portland noted two factors: annual service delays and good ratings in passenger surveys.
- Salt Lake City: Main indicator was combination of ride quality and reliability.

27. Which maintenance functions are to some extent covered by collective bargaining agreements? (Choose any that apply)

- Dallas noted that because Texas is a right-to-work state it has no union agreements.
- San Diego added facilities as a function.

28. What guideway maintenance functions are outsourced?

- Dallas noted that wayside graffiti removal is done both by in-house labor and contracted labor.
- Pittsburgh added that it does 50% of its landscaping work in-house, 50% through contracts, and it does 70% of its communication system repairs in-house.

29. Do any other agencies help with system maintenance?

- San Francisco: Some street painting (clearance lines and curbs) are painted by Department of Parking and Traffic.

Facilities and Equipment Maintenance

30. In your opinion, what is the single main indicator of good facility maintenance?

- Houston noted that good ratings would assume that cleaning and repairs are routinely performed per our policies or as required.
- Portland noted two indicators: cleanliness and number of things that needed to be fixed.
- Salt Lake City said indicator was a combination of cleanliness and low number of things that needed to be fixed.

31. Does you system have CCTV coverage of stations or an Automatic Train Information System?

- Dallas added that it has public address/variable message boards at some locations.

32. Do these features require more than expected maintenance?

- Houston: CCTV—not more repair than we had expected; ATIS—more than we had expected.

33. What maintenance functions are outsourced?

- Cleveland noted that the maintenance of the Gateway Walkway is outsourced.
- Dallas noted that for the repair and servicing of the agency's motor pool, its maintenance vehicles, its stations, and its tunnels and bridges the work is done partly in-house and partly through outside contractors.
- Houston noted that light cleaning and repair are done in-house, but heavy cleaning and repair is outsourced.
- Pittsburgh noted that 20% of its building repair work is done with outside contractors.

APPENDIX D

Light Rail Transit Maintenance Staff Information for Three Other Systems

Buffalo, Dallas, and Philadelphia LRT Systems

	Number of FTEs							
		Maintenance of Way						
LRT System/ Employee Type	Revenue Vehicle Maintenance	Administration	Track and Wayside	Traction Power and Overhead Catenary	Signals and Commun.	Stations	Maint. Facility(ies)	Fare Equipment
Buffalo								
Management	4	4	1	2	1	1		0
Labor	25	0	4	13	20	24		5
Clerical	0	5	0	0	0	0		0
Dallas (bus, LRT, and facilities maint. is combined; allocation to LRT is estimated)								
Management	17.14	3.4	8.52	5.57	14.72	8.12	3.18	2.88
Labor	98	0	30	34	38	25	4	17
Clerical	2	2	1	1	2	1	0	0
Philadelphia (staffing breakout is estimated)								
Management	80	60	20	8	16	10	10	10
Labor	675	0	120	40	40	80	40	50
Clerical	8	10	3	2	2	2	3	1

Staff Productivity Indicators

			Maintenance of Way						
	Vehicle Maintenance Staff per Vehicle in Maximum Service	Vehicle Maintenance Staff per Fleet Vehicle	Administrative Staff per Track-Mile (T-M)	Track and Wayside Maintenance Staff per T-M	Traction Power and Overhead Catenary Maintenance Staff per T-M	Signals and Communication Maintenance Staff per T-M	Station Maintenance Staff per Station	Facility Maintenance Staff per Maintenance Facility	Fare Equipment Maintenance Staff per TVM
Buffalo	1.26	1.07	0.32	0.40	1.21	1.69	1.56		0.12
Dallas	1.37	1.21	0.03	0.38	0.39	0.52	0.95	7.18	0.17
Philadelphia	6.57	5.35	0.35	0.82	0.28	0.33	3.75	16.67	N/A

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation