TRANSIT COOPERATIVE RESEARCH PROGRAM

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The Federal Transit Administration

TCRP Synthesis 15

System-Specific Spare Rail Vehicle Ratios

A Synthesis of Transit Practice

Transportation Research Board
National Research Council

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Synthesis of Transit Practice 15

System-Specific Spare Rail Vehicle Ratios

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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 Transit 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 vice 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 anytime. It is the responsibility of the TOPS Committee to formulate the tesearch 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 the Transportation Research Board 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. TCRP results support and complement other ongoing transit research and training programs.

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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

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PREFACE

A vast storehouse of information exists on many subjects of concern to the transit industry. This information has resulted from research and from the successful application of solutions to problems by individuals or organizations. There is a continuing need to provide a systematic means for compiling this information and making it available to the entire transit community in a usable format. The Transit Cooperative Research Program includes a synthesis series designed to search for and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in subject areas of concern to the transit industry.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

This synthesis will be of interest to transit agency general managers; rail planning, operations, maintenance, and policy personnel; and Federal Transit Administration staff, transportation consultants and engineers; and vehicle manufacturers. This synthesis addreses the system-specific variables that directly impact fleet size, and the spare ratios that are maintained by individual transit agencies. From the information obtained, it appears that most rail transit agencies closely monitor the spare vehicles they maintain to maximize efficiency and thereby reduce operating costs.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, the Transit Cooperative Research Program (TCRP) Synthesis Project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common transit issues and problems, and synthesizing available information. The synthesis reports from this endeavor constitute a TCRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific problems or sets of closely related problems.

This report of the Transportation Research Board describes operating environments at 21 selected rail transit agencies of various sizes in key geographical locations in North America. It contains survey information about operating practices, impediments, and strategies used to appropriately size fleets within each agency's operating context.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of public transportation agencies. A topic panel of experts in the subject area was established to guide the research in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

CONTENTS

1 SUMMARY

4 CHAPTER ONE INTRODUCTION
Background, 4
Study Objectives and Methodology, 4
Spare Ratio Issues, 4

12 CHAPTER TWO SPARE RATIO METHODOLOGY
Background,
Formula,
Selected Practices,
Individualized Issues,

15 CHAPTER THREE SYSTEM-SPECIFIC VARIABLES
Heavy Rail Systems,
Specific Problems of Older Heavy Rail Systems,
Canadian Heavy Rail Systems,
Light Rail Systems,
Commuter Rail Systems,

32 CHAPTER FOUR SIZING THE FLEET
Impediments,
Strategies,
Discussion,

34 CHAPTER FIVE CONCLUSIONS
Critical Variables,
Conclusions of FTA Study,
Discussion,

37 GLOSSARY

39 APPENDIX A QUESTIONNAIRE

43 APPENDIX B UMTA CIRCULAR C 9030.1A

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SYSTEM-SPECIFIC SPARE RAIL VEHICLE RATIOS

SUMMARY

Throughout the transit industry today, rail transit officials are exploring ways to improve fleet management, increase the quality of service, reduce operating costs, and survive diminishing capital and operating funds. Simultaneously, state and federal funding agencies are closely monitoring rail systems to ensure that agencies are operating in a cost-effective manner. A special area of focus is the number of spare vehicles rail transit systems maintain in their total active fleets. Excess spare vehicles can impact cost and compromise fleet quality. A key to good fleet management is maintaining "just enough" railcars to meet service requirements, with adequate spares to sustain a good maintenance program and to provide for moderate shifts in service needs.

Many factors influence the number of spare vehicles a given agency chooses to own and operate at any particular time. This synthesis explores these variables, and findings are based on a survey of 21 heavy rail, light rail, and commuter rail systems in the United States and Canada. The survey results revealed wide variances not only in the actual spare ratios reported by the transit agencies, but also in the methodologies used to calculate the ratio.

Issues that directly impact fleet size and the spare ratios maintained by individual rail systems are addressed in this synthesis. Results from the study for this synthesis demonstrate that most rail agencies already closely monitor the number of spare vehicles they maintain to maximize efficiency and thereby reduce operating costs. In May 1994, the Federal Transit Administration (FTA) released its own *National Rail Spare Ratio Study*, which acknowledges some of the unique factors that determine the number of spare vehicles at rail properties. The FTA report confirmed that rapid transit and commuter rail systems generally have lowered their spare ratios over the past 7 years.

Nonetheless, there is a national dialog underway regarding improved fleet management with constrained spare ratios. Also being deliberated is whether a specific uniform numerical spare ratio would be a useful target for operating and oversight officials. Currently, there is no specific FTA guideline for a spare ratio for rail fleets because FTA recognizes that rail transit operations tend to be highly individualized. Even officials of rail systems with lean fleets report that any guideline, regardless of its authority, may impair their efforts to furnish quality service. Rail transit systems face a number of key issues that uniquely affect their spare ratio. Perhaps the most significant is the loss of ridership, which has reduced peak vehicle requirements. Systems in older urban environments have been particularly affected by changing demographics and lost ridership. With idle vehicles, the spare ratio for these fleets has risen. Excess vehicles are not readily disposed of nor can they be transferred regularly to other properties. Differences in physical and operating environments usually lead to

customized and noninterchangeable rail rolling stock. Newer systems face different but equally significant problems. In retrospect, many of these systems purchased larger fleets than were required at opening to accommodate projections of ridership growth.

Rail transit officials identified the following specific factors as having a major influence on the number of spare vehicles they must maintain to properly manage their fleets:

Factors that tend to raise the spare ratio include the following:

- Aging fleets with high maintenance downtime
- Gap trains used in service but not included in peak vehicle requirement
- Difficulties in disposing of surplus cars
- Cost of retiring cars that have not reached the end of their useful life
- Concerns that fleet reductions will compromise quality service objectives
- Concerns that downsizing will impair ability to meet unexpected future demand
- Hopes that current ridership declines will turn out to be temporary
- Heavy overhaul and rebuild programs that take vehicles out of service
- Difficulties in providing passenger amenities that take vehicles out of service for extended periods of time
- Extensive use of vehicles in married pairs and multiple-unit consists.

Factors that tend to reduce the spare ratio include the following:

- Quality maintenance programs that lead to high vehicle availability
- Ability to temporarily remove excess cars from total active fleet for short periods
- Capability to move cars between lines in same system
- Maintenance labor agreements conducive to quality improvements
- Quality maintenance employees
- A "lean" fleet management philosophy
- Ability to lend/borrow or buy/sell vehicles from other agencies
- Limited or costly storage space, particularly in city centers
- Ability to procure "standard" cars that are interchangeable within a system and with other systems
- Recognition that inactive cars often lead to maintenance problems
- Ability to combine with other agencies in joint railcar procurements
- Effective use of "options to buy" procurement strategies.

How each agency responds to any one or a combination of these factors determines both its spare ratio and the methodology used to calculate the spare ratio.

The study for this synthesis revealed that the formula used to calculate the spare ratio varies among rail systems. The differences in the manner in which the ratio is calculated are significant. Particular situations described in this synthesis illustrate that the spare ratio used by a rail transit system is directly tied to the needs of the agency. In each of the systems profiled, staff have developed systems that work for their agencies, providing sufficient vehicles to accomplish their objectives for quality service. The responding agencies agreed that general standards should be developed to define the spare ratio and its components, and that the process should take into account the complex and individualized issues facing rail systems.

The challenge for the transit industry today is to achieve a realistic and efficient spare ratio within the context of demanding operational requirements; quality service standards; pre-existing rail fleets and routes; anticipated near-term ridership levels; demands of maintenance, overhaul, and rebuild programs; extended procurement cycles; and difficult disposal procedures. The survey findings for this synthesis show that spare ratios and operational and service factors related to spare ratios require careful thought before a consensus can be reached regarding definitions, methodology, and specific spare ratio targets. The objective is to manage fleet size in a way that reduces life-cycle costs without diminishing service standards. This synthesis is the first step in addressing the complex issues raised by the use of spare ratios in fleet management. There is a need to call attention to many concerns raised by the survey respondents. From the many discussions with respondents, it is apparent that transit professionals are eager for more information on how to manage better with less. This synthesis may shed some early light on the subject of railcar spare ratios and help to initiate a discussion within and among transit agencies and between operating and funding agencies.

CHAPTER ONE

INTRODUCTION

BACKGROUND

Today, rail transit agencies are struggling to provide adequate daily service, to increase ridership, to manage aging fleets with fewer resources, and to control operating costs. With tightening transit budgets, efficient fleet operation is of critical importance. A key contributor to efficiency is an appropriate fleet size without excess spare vehicles.

In May 1994, the Federal Transit Administration (FTA) published the *National Rail Spare Ratio Study*, which examined the spare ratio levels of commuter and heavy rail transit systems nationally for the 1985-1991 period. Based on data from the Section 15 Annual Report, the study found that between 1986 and 1991, heavy rail agencies nationally lowered their operating spare ratios from 45.6 to the 30 percent level. Commuter rail transit systems ranged from 18 to 34 percent. Overall, the larger heavy and commuter rail agencies are operating at lower spare ratio levels nationally. The smaller agencies are also lowering their spare ratio levels over a 7-year period. While encouraging transit agencies to further adjust fleet sizes to permit more efficient maintenance and management, FTA recognizes that there are sometimes valid reasons for high spare ratios at individual agencies. The factors cited in the FTA report, and supported in the responses to this survey, factors such as poor maintenance performance, overage fleets, use of gap trains for emergency service, untimely disposal of nonactive railcars, and extended procurement cycles, often led to elevated spare ratios.

The importance of fleet size and the proper spare ratio has become the subject of much debate in the industry and among funding agencies that are examining this critical question. The current FTA regulations do not recommend or require any specific spare ratio for rail systems. Rail transit maintenance officials generally concur that a single standard spare ratio for all rail systems is inappropriate because of the numerous unique factors discussed below. They are concerned that a fleet reduction program to achieve a standard spare ratio, without proper flexibility, could affect federal funding for vehicle replacement and rehabilitation programs, and could undercut their efforts to achieve service improvements and increase ridership. In the interim, it is vitally important that rail transit professionals monitor spare ratios to ensure that they are maintaining and managing their fleets in the most cost-effective manner.

SYNTHESIS OBJECTIVES AND METHODOLOGY

The purpose of this synthesis is to identify and document the specific operating, service, and other factors that affect rail system spare ratios; to highlight those practices and programs in place at specific agencies that increase fleet efficiency and decrease spare ratios; and to identify the needs of fleet management in resolving the issues raised in this study.

North American transit agencies of various sizes with different operating characteristics were selected to report on their individual environments. Twenty-one rail agencies in key geographical areas responded to a questionnaire circulated for this study. Follow-up telephone calls and site visits were made to clarify issues and to identify specific variables that influenced the individual agencies' spare ratios. Seventeen of the agencies are located within the United States and four are in Canada. Information was reported on 25 different mode examples, 14 rapid transit, 6 light rail, and 5 commuter rail systems.

Table 1 identifies the responding agencies and provides relevant information such as fleet size, age, and characteristics; ridership statistics; reported spare ratios; and maintenance performance and practices. All agency-specific data used in this synthesis, including the reported spare ratios, were provided by the respondents for 1993 and 1994 unless otherwise indicated. The survey responses revealed a significant variance in spare ratios and how they were calculated. Some respondents included gap trains in their calculation of peak vehicle requirement (PVR) and some excluded railcars scheduled for programmed maintenance activities. No attempt was made to reconcile the spare ratios reported, nor is a comparative analysis of the spare ratios of the agencies included in this discussion. The reported spare ratios are included to illustrate the differences in calculation and interpretation rather than as a true representation of the actual spare ratios or as comparable spare ratios calculated according to a consistent formula.

SPARE RATIO ISSUES

Ridership

Responding agencies reported several conditions that require vehicles in excess of the agencies' PVR. Sometimes, the excess vehicles are directly tied to declining ridership, which the agencies fully expect to regain. In these cases, the agencies believe they should maintain the current fleet size to accommodate the anticipated increase. A number of agencies reported that the excess vehicles are required to fund planned expansions in the near future either with new lines or new services to meet revived or changed ridership patterns. In these circumstances, decreasing the fleet size may not make sense given the lead time involved in purchasing new vehicles. All of the transit agencies have initiatives designed to increase ridership and anticipate a boost from the Clean Air Act Amendments such as the Employer Trip Reduction Program and other inducements to taking mass transit. Transit agencies recognize that ridership fluctuations are dynamic and sometimes capricious and that long-term decisions should not be made solely on today's ridership numbers. New or additional vehicles cannot be bought or leased quickly in response to sudden ridership increases. Transit systems must be ready to meet the needs of new customers, lest these discretionary riders seek alternative means of transportation.

TABLE 1

SPARE VEHICLE RATIOS

System	Fleet Characteristics	Reported Spare Ratio	Maintenance Procedures
Heavy Rail Rapid Transit Systems			
MTA New York City Transit (MTA NYCT) Elevated and sub-way; 23 lines	Size/Consist: 5,806/10 Annual unlinked passenger trips: 1,373.0 mill PVR: 4,948 Fleet ave. age: 20.1 yr Married: 70% Single: 25% Consist: 5% 5-car Integrated lines: No	Division A = 6% Division B = 8% Excludes cars for scheduled mainte-nance	Gap in PVR: 50 Inspection cycles: every 66 days (9,000 to 11,000 mi) Component overhaul cycles: Airbrake valves-4 yr, Trucks, HVAC, Brake valves-6 yr, Air compressor, battery sets-7 yr Out/running repairs: 3% Out/all repairs: 8% Amenities policy: No service if car is defective
Chicago Transit Authority (CTA) Elevated and Subway; 7 lines	Size/Consist: 1,190/7 Annual unlinked passenger trips: 118.0 mill PVR: 944 Fleet ave. age: 10.8 yr Married Integrated: All lines	20.4% (Adds 20% for scheduled main-tenance in spare ratio calculation)	Gap in PVR: 78 Inspection cycles: 90 days or 6,000 mi; midlife-12 yr, truck & component-6 yr, life exten-25 yr; Out/running repairs: 7.3% Out/all reasons: 18% Amenities policy: cars held for no heat, no a/c
Washington Metropolitan Area Transit Authority (WMATA) Elevated and Subway; 5 lines	Size/Consist: 764/6 Annual unlinked passenger trips: 149.5 mill PVR: 588 Fleet ave. age: 10.5 yr Married Integrated: All lines	20% (adds 20% for scheduled maintenance)	Gap in PVR: 48 (4 used for revenue collection only) Inspection cycles: 5,000 mi, 30,000 and 60,000 mi; Out/running repairs: 7.8% Out/all reasons: 15.5% Amenities policy: cars held for no lights, no a/c,
San Francisco Bay Area Rapid Transit (BART) At Grade, Elevated, and Subway; 4 lines	Size/Consist: 575/9 Annual unlinked passenger trips: 78.3 mil PVR: 453 Fleet ave. age: 16 yr Single Integrated: 147 cars fully	20% PVR includes Fairlande float yard	Gap in PVR: 40 Inspection cycles: 550-600 hours; plan to contract major overhaul; Out/running repairs: 7.8% Amenities policy:cars held for cleanliness, offensive graffiti, a/c
Massachusettes Bay Transportation Authority (MBTA) Subway, 3 lines	Size/Consist: 386 Red Line: 196/5; Orange Line: 120/6; Blue Line: 70/4 Annual unlinked passenger trips: 109.8 mil PVR: 310 (Red: 152, Orange: 102, Blue:56) Fleet ave. age: Red:18-21 yr Orange: 14 yr Blue:16 yr Married Integrated: No	Red Line: 29% Orange Line: 18% Blue Line: 25%	Gap in PVR: 3 Red Line trains Inspection cycles: Red Line: 7,500 mi Orange Line: 8,500 mi Blue Line: 8,500 mi Major overhaul: No Out/running repairs: Red-34%, Orange-14%, Blue-10% Out/all reasons: 10% Amenities policy: cars held for a/c, heat, cleanliness

TABLE 1

SPARE VEHICLE RATIOS (Continued)

System	Fleet Characteristics	Reported Spare Ratio	Maintenance Procedures
Heavy Rail Rapid Transit Systems			
Southeastern Pennsylvania Transportation Authority (SEPTA) Elevated and Subway, System 1+1 only	Size/Consist: 342 Blue: 217/6 Orange: 125/5 Annual unlinked passenger trips: Blue Line: 54.7 mil Orange Line: 37.8 mil PVR: Blue Line: 168 Orange Line: 113 Fleet ave. age: Blue Line: 34 yr Orange Line: 13 yr Married: Blue Single: Orange Integrated: No	Blue Line: 29% Orange Line: 10.6%	Gap in PVR: No Inspection cycles: Blue Line: 15, 45, & 180 days Orange Line: 14 days & 3 mos Major Overhauls: Blue Line: No Orange Line: 5 yr; major component 10 yr & midlife Out/running repairs: Blue Line: 9 Orange Line: 0 Out/all reasons: Blue Line: 74 Orange Line: 11 Amenities policy: cars held for a/c, heat, cleanliness, graffiti
Port Authority Trans Hudson Corporation (PATH) Subway, New York, New York, 4 lines	Size/Consist: 342/7.5 Annual unlinked passenger trips: 60.1 mil PVR: 297 Fleet ave. age: 20.8 yr Single Integrated: lead & trailer cars	13%	Gap in PVR: 15 Inspection cycles: 90 days Major overhaul: Door: 5-7 yr A/C: 5-7 yr Truck: 7-8 yr Motor: 300,000 mi Gear: 8 yr Out/running repairs: 4% Out/all reasons: 14% Amenities policy: cars held for cleanliness, a/c, & safety defects
Metropolitan Atlanta Rapid Transit Authority (MARTA) Subway, elevated, at grade; 2 lines	Size/Consist: 240/7 Annual unlinked passenger trips: 65.5 mil PVR: 158 Fleet ave. age: 11.5 yr Married: 220 Integrated: Yes	37%	Gap in PVR: 0 Inspection cycles: 60 days Major overhaul: midlife components, removed & replaced off-property Out/running repairs: 8% Out/all reasons: 35% Amenities policy: cars held for a/c & heat
Metro-Dade (Florida) Transit Authority Elevated, 1 line	Size/Consist: 136/6 Annual unlinked passenger trips: 13.7 mil PVR: 76 Fleet ave. age: 10 yr Married Integrated: Yes	78.9%	Gap in PVR: 0 Inspection cycles: 45, 90, 180 days annual Major overhaul: Pending Out/running repairs: 16 Out/all reasons: 42 Amenities policy: cars held for cleanliness, a/c, graffiti, torn seats

TABLE 1

SPARE VEHICLE RATIOS *(Continued)*

System	Fleet Characteristics	Reported Spare Ratio	Maintenance Procedures
Heavy Rail Rapid Transit Systems			
Port Authority Transit Corp. (PATCO), Lindenwold, New Jersey 1 line	Size/Consist: 121/6 Annual unlinked passenger trips: 11.2 mil PVR: 102 Fleet ave. age: 20.4 yr Married: 79% semi-Permanent Integrated: Yes	15.7%	Gap in PVR: 0 (6 cars for relay train not in PVR) Inspection cycles: monthly $15,000 mi, Airbrake: 48 mo Major overhaul: midlife (15-25 yr) Out/running repairs: 1% Out/all reasons: 10% Amenities policy: cars held for all Passenger amenities
Greater Cleveland Regional Transit Authority (GCRTA) Elevated except At airport, 2 lines	Size/Consist: 60/2-3 Annual unlinked passenger trips: 40 mil PVR: 30 Fleet ave. age: 11 yr Single Integrated: Yes	41%	Gap in PVR: 0 Inspection cycles: Minor: 3,000 mi; Major: 5,000 mi Major overhauls: 0 Out/running repairs: 5 Out/all reasons: 17 Amenities policy: cars held for cleanliness, torn seats, a/c & heat
Toronto Transit Commission (TTC) Inspection cycles: Standard every 15,000 mi; Subway, Some at grade; 2 lines	Size/Consist: 622/2-3 Annual unlinked passenger trips: 260.2 million PVR: 492 Fleet ave. age: 4-32 yr Married Integrated: No	15% (Excludes scheduled maintenance in PVR)	Gap in PVR: Yes Safety every 28 days Major overhaul: Specific component rebuild Out/running repair: 2.6% Out/all reasons: 11.6% Amenities policy: If extras available, cars held For cleanliness, a/c, heat, pass. assist. strips
Montreal Urban Community Transit Corporation (Montreal Subway) 4 lines	Size/Consist: 759/9 Annual unlinked passenger Trips: 356.2 million PVR: 565 Fleet ave. age: 21.4 yr Married: 3 cars permanent Pairs Integrated: Yes	34%	Gap in PVR: Yes Inspect. cycles: Safety at 9000 km Major overhaul: completed 39 cars, Bodywork only Out/running repairs: 6% Out/all reasons: 17.3 % Amenities policy: No
British Columbia Rapid Transit Co. (BC Transit) 1 line	Size/Consist: 130/4 Annual unlinked passenger trips: 35.7 mil PVR: 116 Fleet ave. age: 7.3 yr Married Integrated: Yes	11%	Gap in PVR: 3% Inspect. cycles: Safety-15,000 km & 30,000 kn; Major-120,000 km Major overhauls: truck-7 yr; coupler-7yr; Brakes-7 yr; motors-3/4 yr (LIM) Out/running repairs: off-peak only Out/all reasons: 6 Amenities policy: cars held for vandalism; ride quality; truck or wheel noise

TABLE 1

SPARE VEHICLE RATIOS *(Continued)*

System	Fleet Characteristics	Reported Spare Ratio	Maintenance Procedures
Light Rail Rapid Transit Systems			
Massachusetts Bay Transportation Authority (MBTA)	Size/Consist: 180/2 Annual unlinked passenger trips: 60.0 mil PVR: 141 Fleet ave. age: 12.6 yr Single Integrated: No	31%	Gap in PVR: 3.5% am; 5.7% pm Inspection cycles: Boeing-3,000 mi; Type 7- 5,000 mi Major Overhauls: No Out/running repairs: 9.4 % Out/all reasons: 13.9 % Amenities policy: cars held for a/c, heat, Cleanliness, graffiti
San Francisco Municipal Railway (MUNI) street level, 6 lines	Size/Consist: 126/2 Annual unlinked passenger trips: 40,000 PVR: 101 Fleet ave.age: 14 yr Single Integrated: No	NA	Gap in PVR: 0 Inspection cycles: weekly, every 6,000 mi; Signals at 6,000 mi Major overhauls: No Out/running repairs: 10.3% Out/all reasons: *15.1%* Amenities policy: none
San Diego Trolley, Inc. Dedicated Right-of-way, 2 lines	Size/Consist: 71/3 Annual unlinked passenger trips: 16.0 PVR: 56 Fleet ave. age: 4-13 yr Single Integrated: Yes	16.9%	Gap in PVR: 0 Inspection cycles: weekly, monthly, 3 months, Annually Major overhauls: 3 yr Out/running repairs: 7% Out/all reasons: 15% Amenities policy: NA
Port Authority of Allegheny County (PA Transit) 4 lines	Size/Consist: 59/1 Annual linked passenger trips: 9.0 mil PVR: 43 Fleet ave. age: 9 yr Single Integrated: Yes	28%	Gap in PVR: 7% Inspection cycles: Routine-5,000 mi; Lubrication-15,000 mi; Routine-30,000 mi Major overhauls: LRV-6yr; PCC-2 yr Out/running repairs: 3.4% Out/all reasons: 18.6 % Amenities policy: cars held for heat, ventilation
Greater Cleveland Regional Transit Authority (GCRT) 1 line	Size/Consist: 48/2 Annual linked passenger trips: 2.7 mil PVR: 24 Fleet ave. age: 13 yr Single Integrated: No	27%	Gap in PVR: No, extra cars in bad weather Inspection cycles: Minor-3,000 mi; major-5,000 mi Major overhauls: every 4 yr Out/running repairs: 5 Out/all reasons: 17 Amenities policy: cars held for cleanliness, torn seats, a/c, heat
Toronto Transit Commission (TTC) 1 line LRV	Size/Consist: 267 LRV/ 1 Trolley Annual unlinked passenger trips: 70 mil/ 6 mil (trolley) PRV: 183 Fleet ave. age: 5-43 yr Single Integrated: No	12%	Gap in PVR: Yes Inspection cycles: 5,400 mi Major overhaul: Wheels, trucks - 4 yr; compressor, air dryer - 2 yr Out/running repairs: 0% Out/all reasons: 5% Amenities policy: cars held for cleanliness, torn seats, a/c, heat

TABLE 1

SPARE VEHICLE RATIOS *(Continued)*

System	Fleet Characteristics	Reported Spare Ratio	Maintenance Procedures
Commuter Systems			
Long Island Rail Road (LIRR) 6 lines	Size/Consist: MU-932; DHC-177; Bi-Level-10; Parlor-12; Loc-51; PU-14 total= 1,196 Annual unlinked passenger trips: 92.4 mil PVR: MU/E-818; DHC-134; Loc,PP- 52 total =1,004 Fleet ave. age: MU-27 yr; DHC-35 yr; Loc-18 yr; PU-42 Married: MU & Bi-levels Integrated: MU-Yes; DHC & Loc; PU & PP	12.2% (Varies by subset)	Gap in PVR: No Inspection cycles: 2B-daily; 45-day PL; 92 day 91; 2 air brake Major overhaul: MU component life cycle 2,4,6,8,10,12 yrs; Loc 6 yr Out/running repairs: 5% MU Out/all reasons: 12.2%; 18.6% diesels Amenities policy: cars held for a/c, heat
METRA (Chicago) 6 lines	Size/Consist: Loc-130; DHC-686; MU-165 total = 981/8 Annual unlinked passenger trips: 72.6 mil PVR: Loc-123; DHC-662; MU-145 Out/all reasons: 2.7% Fleet ave. age:Loc-11.3 yr; DHC-28 yr; MU-21 yr Single Integrated: MU do not integrate w/ DHC	3.5%	Gap in PVR: No Inspection cycles: Daily, 45 day, 92 day, 184 annual Major overhaul: Loc-10 yr; Cars-15 yr Out/running repairs: 0 Amenities policy: cars held for a/c
New Jersey Transit Corporation (NJ Transit) 13 lines	Size/Consist: Loc-80,DHC- 389,MU-300 total = 769/2 Annual unlinked passenger trips: 44.4 mil (excludes Metro North contracted service) PVR: 582 Fleet ave. age: Loc-15.4 yr, DHC-14.8 yr, MU-16.6 yr Married: 135 MU Integrated: No	19.9% (excludes long-term out-of- service)	Gap in PVR: No Inspection cycles: FRA-45, 60, & 90 days; NNT-180 days; FRA-brake on MME Major overhauls:Loc-4 yr, Major-8 yr, Loc Remaining-16-20 yr Out/running repairs: 4% MU/DHC Out/all reasons: 17% Amenities policy: cars held for cleanliness, Nonfunctional toilets
Southeastern Pennsylvania Transportation Authority (SEPTA) 7 lines	Size/Consist: Loc-7, MU- 304, PP-35 total = 346/3 Annual unlinked passenger trips: 20.3 mil PVR: 265 Fleet ave. age: 20.2 yr Married: 92 MU pairs Integrated: Yes	21%	Gap in PVR: 3.4% Inspection cycles: 60 & 736 days Major overhauls: Silverlines-5 yr Out/running repairs: 8.6% Out/all reasons: 22.5% Amenities policy: cars held for a/c, heat, extremely dirty, graffiti

TABLE 1

SPARE VEHICLE RATIOS *(Continued)*

System	Fleet Characteristics	Reported Spare Ratio	Maintenance Procedures
Commuter Systems			
GO Transit (Toronto)	Size/Consist: 306/10 Annual unlinked passenger PVR: 278 inc. 13 for service Fleet ave. age: Loc-4 yr, DHC-9 yr Single Integrated: Yes	10.8%	Gap in PVR: 1 spare train (10 cars) Inspection cycles: Loc-10 days, DHC7 lines trips: 25.3 mil daily & bi-weekly Major Overhauls: 5 yr Out/running repairs: 2.9% Out/all reasons: 10.8% Amenities policy: cars held for a/c, heat, rough ride

DHC = diesel haul coach
MU = multiple unit (electric) NA = not available
PP = push/pull
PU = power unit
PVR = peak vehicle requirement

Fleet Cost

Transit professionals at responding agencies acknowledged that maintaining excess vehicle inventory can be very costly because of the labor and materials costs associated with fleet maintenance and storage, and can also affect the quality of fleet maintenance, thereby decreasing overall fleet reliability. However, survey respondents were equally concerned about the problems of running with too lean a fleet and the potential disruption of service. Without sufficient spares, unexpected events, bad weather, or unanticipated maintenance problems can greatly affect service delivery.

Maintenance Issues

Survey respondents asserted that storing vehicles in limited yard space may also be impractical. Space often comes at a premium, particularly in urban centers. Further, downsizing maintenance staff may not be feasible or productive given the limited flexibility to alter work rules because of collective bargaining agreements. Unless the agency can properly maintain the vehicles and reduce labor costs, warehousing vehicles is of little or no economic value. Stored vehicles still must be maintained to ensure the viability or usability of the cars. Careful consideration must be given to the conditions under which vehicles will be stored.

Procurement Cycles

Because of the long lead time required to procure new railcars (generally 3 to 5 years from design specification to arrival of the railcar(s) on the property), many agencies want to purchase more cars than are needed immediately. In addition, to prepare for possible increases in ridership, or unexpectedly high ridership on new systems, there is a financial advantage to buying large quantities. For most agencies, there is no ability to borrow cars from other agencies or even to move vehicles within a single agency due to the high customization of individual rail lines.

Age of Fleet

Fleet age may have a major and dramatic impact on the spare ratio, especially if the fleet has not had a mid-life overhaul. Deferred maintenance, coupled with the absence of a major overhaul program, can lead to more frequent breakdowns and in-service failures, requiring more spares.

Intra-Agency Incompatibility

Some transit systems were built over several decades with different operating physical environments within the system, precluding the interchange of railcars on different lines. When an agency cannot operate different types of equipment on other lines, a different number of spare vehicles is required for each subset, which increases the overall need for spare vehicles.

Married Pairs

If the system uses married pairs, the number of vehicles required may increase because when one car fails, the other unaffected car is often pulled from service as well. Although many commuter rail systems uncouple married pairs at the end of the line, few rapid transit systems will do this while the train is in service.

Maintenance Programs

Overhaul

Major overhaul and manufacturing programs are beneficial in extending the useful life of rail vehicles and improving vehicle availability in the short term. However, they add to the spare vehicle requirement. Transit systems must have sufficient replacement vehicles for cars in repair and out of service for extended periods of time. This holds true also for an aggressive inspection program. The more frequently cars are removed from service for inspections and scheduled maintenance, the higher the number of replacement vehicles that must be on hand. However, several rapid transit systems do uncouple pairs from trains at the end of a rush hour to reduce the length of a train. Port Authority Transit Corporation (PATCO) and Chicago Transit Authority (CTA) adjust train lengths before and after each rush hour.

New versus Old Component Parts

Scheduling heavy maintenance and rehabilitation depends to some extent on the availability of spare parts, which presents some difficulties, given the customized nature of the equipment, foreign markets, and the difficulty in adapting new parts to older vehicles. This factor can extend the time a vehicle is out of service.

Overhaul versus Remanufacturing

Several agencies now overhaul component parts on a timed schedule, replacing motors, wheels, transmissions, or other components on an as-needed basis or in accord with the manufacturers' recommendations to increase vehicle availability. Remanufacturing railcars includes structured restoration, takes extended time, and is often done off-property. Both overhaul and zremanufacturing programs require substantial spare vehicles.

Physical Operating Environment Including Weather Conditions

Severe winter weather affects both the reliability of service and the wear and tear on equipment, particularly for elevated or at-grade systems. Very cold air can cause rails to split. Elevated systems can lose brake shoes or sustain damage to motors and wheels due to snow and ice. Systems that run atgrade, operating in highway medians, are subject to road salt and other snow-removal pollutants.

Passenger Amenities

As the transit industry tries to be more responsive to commuter needs and attract new riders, quality of service delivery has become a critical issue. Quality control programs are a key to customer-focused initiatives. Most agencies have responded with stringent programs, requiring the removal from commuter service of dirty cars and those without operable toilets or functioning heating and cooling systems. Passengers, particularly those who are not transit dependent, will leave mass transit if minimal quality service is not provided. Standards for such characteristics as sitting versus standing space, lighting, and space between seats must be adequate to make sure that rail transit remains competitive with other forms of transportation. Officials from responding agencies asserted the importance of these programs, despite their impact on spare ratio.

Generally, many transit personnel believe that there should be a standardized reporting procedure and a formula for determining the spare ratios at each unique transit agency. Because of system-specific variables, each agency has special concerns regarding fleet management and provision of timely and quality service. Establishing realistic spare ratios would help agencies to improve fleet management and to maintain quality service in today's highly visible transit market.

CHAPTER TWO

SPARE RATIO METHODOLOGY

BACKGROUND

This chapter reviews the wide variations in methodology that each surveyed agency employs in calculating the spare ratio. Where appropriate, it also provides a rationale for the use of atypical calculations.

The data presented in this and the following chapters were submitted by the respondents for calendar year 1993 and, in some instances, for early 1994. However, the basic assumptions and issues raised by the participants remain key concerns and are still open for discussion and common understanding.

The spare ratios presented next were supplied by responding agencies and are presented to frame the discussion on spare ratio issues raised by the participants during follow-up interviews. The spare ratios presented in most cases are not comparable. To fully illustrate the specific conditions and factors influencing the need for spare vehicles at each agency, substantial information on fleet size, peak vehicle requirement (PVR), and the various components used in calculating the spare ratio has been provided in this discussion and in Table 1 (see Chapter 1).

FORMULA

As demonstrated in the survey responses, the formula used to calculate spare ratio varies among rail systems and, in some instances, is not in accord with the suggested FTA formula in the Section 15 Glossary of Transit Terms. The differences in how the ratio is calculated are significant. By adding gap trains to the PVR or excluding railcars required to support scheduled heavy maintenance or overhaul programs from the total active fleet (TAF), the resultant spare ratio differs notably from what it would be if the FTA authorized Section 15 methodology were used. In some cases, the TAF has been interpreted to mean total available fleet, which may include only those railcars that are actually "available for service." For example, many maintenance officials do not include in the TAF railcars that are out for long-term repairs but are not ready for retirement or sale. Also, spares are sometimes designated as those vehicles in excess of cars actually available for revenue service, excluding those being held for scheduled maintenance functions including major overhaul programs.

Some agencies include "gap" trains (also known as reserve, standby, or relay trains) in their PVR as if these trains actually were scheduled for service. They are stored along the routes, in terminal pockets, or in the yards for emergency deployment during service breakdowns and may or may not be staffed with a crew. Other agencies use these extra trains in the same manner but do not include them in their PVR. However, many agencies rely on gap trains to support scheduled service.

The introduction of these variations skews the "true" spare ratio, making it difficult to perform comparative analysis. It may also unfairly portray agencies that do not use these variations in their calculations. The nature and impact of these components is also important in analyzing the issue as to whether rail systems should adhere to a specific spare ratio, and how that ratio should be calculated. Some rail transit officials who employ one or more of these atypical methodologies suggest that their variation should be mandated because of the inherent characteristics of rail operations. They point to the system-specific variables for rail agencies that do not exist in bus systems and argue against a formula that applies to both modes.

Although the FTA has no established recommended spare ratio for rail fleets, it has defined the reporting formula to use in determining the spare ratio for Section 15 reporting purposes.

$$\frac{\textbf{Total Active Fleet} - \textbf{Peak Vehicle Requirement}}{\textbf{Peak Vehicle Requirement}} = \textbf{Spare Ratio}$$

For the purposes of this discussion, the applicable terms are defined by FTA according to the glossary for Section 15 as follows:

Total Active Fleet (TAF): All revenue vehicles held at the end of the fiscal year, including those in storage, reserved for contingencies, awaiting sale, etc.

Peak Vehicle Requirement (PVR): The total number of revenue vehicles operated to meet the annual maximum service requirement. This is the revenue vehicle count during the peak season of the year, on the week and day that maximum service is provided. It excludes atypical days and one-time special events.

Spare Vehicles: Revenue vehicles available to the transit agency to accommodate routine and heavy maintenance requirements, also unexpected vehicle breakdowns or accidents, while preserving scheduled service operations. (TAF - PVR = Spare Vehicles)

Spare Ratio Factor: The number of spare vehicles divided by the maximum service PVR, usually expressed as a percentage, e.g., 100 vehicles required and 20 spare vehicles are a 20 percent spare ratio.

SELECTED PRACTICES

An analysis of the survey responses for this synthesis illustrates some methodologies used to determine spare ratio that may vary with the FTA Section 15 reporting formula.

MTA New York City Transit (MTA NYC Transit)

MTA NYC Transit, with a fleet of 5,806 vehicles, does not rely heavily on gap trains--less than 1 percent of the PVR, about 50 cars, are designated as gap trains; the trains are stored in relay positions along various routes. However, that 1 percent is included in the calculation of PVR by the agency. MTA NYC Transit uses a total available fleet instead of TAF, which excludes from the TAF cars undergoing major overhaul or modifications, as well as those in scheduled maintenance system programs. In addition, daily inspection cars, long-term holds, and cars pending scrap are deducted from the TAF.

Running repairs account for approximately 3 percent of the out-of-service vehicles. The spare ratio is calculated as a percentage of the total available fleet. Thus, the spare ratio reported by MTA NYC Transit of 6 percent for division A and 8 percent for division B is significantly different than it would be using the Section 15 FTA reporting formula. Nevertheless, an MTA NYC Transit maintenance facility official asserted that this is the proper way to calculate the spare ratio because the cars are unavailable for revenue service due to planned maintenance activities.

The reported MTA NYC Transit methodology is as follows:

1. The total number of cars in the fleet minus unavailable cars equals available fleet.
2. The total required cars for revenue service are subtracted from the available cars.
3. The difference between required cars and available fleet divided by the available fleet is the spare factor.

This methodology lowers the spare ratio and permits agency staff to ensure that there will be vehicles available for maintenance when necessary.

MTA NYC Transit develops two spare ratios rather than one, because its fleet is divided between two divisions and the cars are not transferable between them. Nevertheless, the reported spare ratios for both divisions are low.

Chicago Transit Authority (CTA)

CTA determines its spare ratio by subtracting the PVR plus terminal spares (gap trains) plus vehicles set aside for scheduled maintenance from the TAF and divides that number by the PVR plus terminal spares (gap trains) plus vehicles set aside for scheduled maintenance. This formula is expressed as follows:

$$\frac{\text{TAF-(PVR + terminal spares + scheduled maintenance)}}{\text{(PVR + terminal spares + scheduled maintenance)}} = \text{Spare Ratio}$$

For example, using 1993 fleet size and PVR statistics, CTA reported a TAF of 1,190 vehicles with a PVR of 866 cars. CTA maintenance officials then add 44 out-of-service vehicles for preventive maintenance and an additional 78 cars (approximately 11 gap trains, one full consist per route per maintenance location) for gap trains, which constitute roughly 8 percent of the PVR, plus the cars included as scheduled maintenance replacements. This raises peak requirement to 944 cars. Thus, the spare ratio is reduced significantly when the gap and other railcars are included in the PVR and not counted as excess vehicles.

The gap trains are stored in the yard and in terminal spare pockets to expeditiously replace cars removed from service. CTA maintenance officials advocate the inclusion of gap trains in the PVR because they operate these trains 70 percent of the time. Ridership is heavy and CTA relies on gap trains to minimize inconvenience to passengers, particularly during harsh Chicago winters. There is a strong incentive at CTA to avoid extended delays in service.

New Jersey Transit Corporation (NJ Transit)

NJ Transit uses a slight variation on the standard method for calculating its spare ratio. NJ Transit has a major overhaul program in place, but when determining its spare ratio, does not deduct the vehicles being overhauled from the total fleet, only those vehicles awaiting long-term repairs (accidents and major repairs) that are out of service for longer than 30 days. These vehicles are subtracted from the TAF to arrive at the total available fleet. NJ Transit sets aside a specific number of vehicles for "shop work," including major overhaul. The balance are considered spare vehicles. On average the "shop target" approximates 20 percent of the total available vehicles.

Washington Metropolitan Area Transit Authority (WMATA)

WMATA also uses a different methodology in calculating its spare ratio. The agency reports only 706 vehicles available for daily revenue operations against a TAF of 764 cars. Fifty-four cars are stored and used to replace cars undergoing an extensive mid-life overhaul program. The PVR of 588 cars (1993) also includes 54 cars (about 9 percent of the PVR) as gap or relay trains that WMATA regularly uses to augment service.

WMATA staff believe that it is appropriate to exclude the stored vehicles and those being rebuilt because they are not available for service and the overhaul program is an extensive and ongoing program with an anticipated completion date of 2002. Approximately 280 mid-life overhauls will be done over the next two years and the balance will be done at 70 per year until the year 2002. WMATA stated that a steady flow of vehicles is needed to support its ambitious overhaul program.

San Francisco Bay Area Rapid Transit District (BART)

BART excludes from the TAF vehicles out of service due to serious accidents, although it anticipates eventually repairing those vehicles for service. In determining its PVR, BART includes cars for scheduled service, plus 10 cars for each of its four yards (40 cars), and extra trains for moving cars in the yards.

Port Authority Trans-Hudson Corporation (PATH), New York, New York

PATH, operative between northern New Jersey and Manhattan, includes 15 gap trains in its PVR. These trains are operating 50 percent of the time each week. In calculating the spare ratio, PATH officials do not exclude cars for scheduled maintenance as do some other agencies. Only a small number of PATH's vehicles undergo scheduled maintenance: three cars are out of service for overhaul on an average day. Given the inclusion of gap trains and the low number of vehicles out of service for maintenance, PATH officials calculate a reasonably low spare ratio.

Port Authority Transit Corporation (PATCO), Lindenwold, New Jersey

PATCO reported that it runs with a very tight fleet. Although PATCO uses extra trains to support service on average 35 to 45 times per week, it does not include them in the peak PVR. PATCO'S maintenance practices seem similar to PATH's. It should be noted that on an average day, PATCO has only 13 vehicles out of service for scheduled and unscheduled maintenance activities.

Toronto Transit Commission (TTC)

While Canadian agencies do not prepare Section 15 reports and are not guided by FTA record-keeping definitions, TTC provides a good example of an agency that has made a significant effort toward managing its fleet while meeting its goals. TTC has developed an agency philosophy regarding the spare ratio for its rail fleet. For its subway system, TTC indicated that it deducts the PVR from the TAF and allocates 15 percent of the remainder for scheduled maintenance. The 15 percent represents the agency's best estimate of the number of vehicles required for budgeted scheduled maintenance, defined as running repairs, inspections, and special project work such as major repairs. The remaining vehicles are considered surplus rather than spare vehicles, and are used to replace vehicles out of service due to unanticipated major work circumstances, such as accidents and/or fleetwide defects. TTC indicates that, although these cars are a part of the TAF, they are used only in emergencies as discussed above. Although there is a plan to retire some of these extra vehicles, the agency plans to hold on to some to accommodate special projects.

INDIVIDUALIZED ISSUES

The particular situations described above illustrate the many instances in which the spare ratio methodology is directly tied to the needs of the agency. In each of the rail systems profiled, officials have developed systems that work for their agencies, providing sufficient vehicles to accomplish their overhaul and inspection requirements, while providing adequate protection to ensure quality service. Responding agencies agreed that although general standards should be developed to define the ratio and its components, the process should take into account the complex and individualized issues facing rail systems. Most respondents pointed out the differences in rail and bus service and contended that similar approaches to spare ratio cannot be applied equitably. The major difference is that trains consist of multi-units (this demands more available cars and more vehicle support than buses), which can be replaced and/or substituted on a one-for-one basis.

CHAPTER THREE

SYSTEM-SPECIFIC VARIABLES

This section provides a general discussion of those systemspecific variables that affect spare ratios at the 21 agencies discussed in this synthesis. The systems are categorized by type (heavy rail, light rail, and commuter rail). Each of these systems offers a different perspective on the problems facing rail agencies in developing overall fleet plans. For example, Metropolitan Atlanta Transit Authority (MARTA) and Metro-Dade (Florida) Transit Authority are new systems that have never achieved the ridership projections predicted when the systems were built. Based on its proposed system size and patronage projections, each agency planned larger systems than are currently in place, and purchased vehicles to support the larger systems, given the long lead time between purchase and vehicle delivery. Although future expansions are anticipated, the delays in building out the systems have been significant and have resulted in spare ratios higher than desired. Conversely, Chicago Transit Authority (CTA) typifies some of the problems facing urban centers with aging infrastructure and large passenger loads, but declining ridership.

As is more thoroughly discussed in the agency profiles, some common issues exist among systems, although variances in degree do occur. Given their dynamic operating environments, most of the respondents stated that they require flexibility in managing spare vehicle fleets. Many operating officials stated that they need extra vehicles, especially if the system runs an older fleet, must handle severe weather conditions, or has a major overhaul program that takes cars out of service for extended periods of time. Further, with the advent of customer service programs that mandate trains be removed from service to maintain quality, operating with inadequate spares can cause frequent disruptions in service. The pressure to "make service" without adequate spare cars may defer needed maintenance, thus causing an undesirable long-term effect on the fleet.

Rail transit officials at the participating agencies stated that any spare ratio formula must take into account the impact of married cars, and in some cases triple sets (as in the Montreal system), which can significantly impact car availability. With its program using 5-car consists, MTA NYC Transit provides valuable information on the cost effectiveness of multiple integrated car consists. Although commuter rail agencies and other systems such as BC Transit can and do uncouple married cars at terminal points, few rapid transit agencies can do so in peak service--with tight headways and heavy passenger loads there just is not enough time. Only a few agencies will uncouple cars for reasons other than a major repair. Semi-permanently married cars cannot run without a mate.

There is a correlation between the number of running repairs a system has during the peak period and the spare ratio, and this issue is discussed. However, the respondents use different standards in defining ordinary maintenance, scheduled maintenance, and running repairs, which makes comparisons and conclusions difficult.

HEAVY RAIL SYSTEMS

The heavy rail systems studied vary in the number of spare vehicles retained to support the peak vehicle requirement (PVR). The respondents urged caution and flexibility regarding the methodology and application of spare ratio calculations. They all indicated that because the operational issues for each property are different, a spare ratio that allows for individualized operating conditions is the most realistic and effective. Further, they believe that bus industry experience should not be used as a model because the rail operating environment is fundamentally different. They note that when a bus fails, only one vehicle is removed from service and passengers can either wait for the next bus or seek alternative forms of transportation. However, when one railcar fails, the entire train, in some cases up to 10 cars, must be removed to facilitate the flow of rail traffic backed up behind the disabled train.

The following is a discussion of the major, system-specific variables that affect the number of spare vehicles required to operate service at each surveyed site.

MTA New York City Transit (MTA NYC Transit)

Fleet Characteristics

MTA NYC Transit operates a fleet of 5,806 vehicles, with an overall average age of 20.1 years, and requires 4,948 vehicles, in the aggregate, to meet daily service on all lines. Of the 4,948 peak vehicles, less than 1 percent (50 cars) are designated gap trains.

In addition, the agency operates two divisions with two different fleets that cannot be interchanged between divisions. Recent data indicate that subdivision "A" has a fleet of 2,563 cars with a 6 percent spare ratio and subdivision "B" has 3,243 cars with an 8 percent spare ratio. Seventy percent of the overall fleet is in married pairs, 25 percent are single cars, and the remaining are 5- and 3-car units. All of the single cars are less than 7 years of age.

Operating Environment

MTA NYC Transit's operating environment makes a large fleet difficult to manage because the fleet operates in the city, and storage space is a key factor in limiting the number of excess spares. Officials indicate that too many cars may impact the quality of the maintenance they provide. A significant portion of the system operates as an elevated system and therefore experiences weather-related maintenance issues. In the winter, snow and ice pose problems, requiring not only functioning heating systems, but also possible maintenance problems with motors and doors. New York summers are hot and air conditioning systems must be maintained in peak working order. Because old fleets require more maintenance, MTA NYC Transit has implemented a preventive maintenance program to maximize efficiency and vehicle availability.

Finally, labor issues at MTA NYC Transit impact productivity.

Maintenance Practices

MTA NYC Transit officials believe that they have had adequate spare vehicles to provide quality service while maintaining cost control. In part, they attribute their success to the reduction of running repairs in recent years to an estimated 3 percent of the out-of-service vehicles. Agency officials indicate that they purposefully reduced the fleet over the last 5 years and have worked diligently to manage with a very tight fleet. With the introduction of scheduled maintenance and mid-life component overhaul programs, improved capital investment in the barns, and the acquisition of new cars, MTA NYC Transit has been able to reduce the number of out-of-service vehicles and limit the number of spare vehicles. In addition, the agency has increased shop productivity by increasing the number of maintenance managers; this, in turn, has reduced the pressure on the operating budget.

MTA NYC Transit has implemented a time-sensitive scheduled maintenance program for component overhauls, which is designed to increase vehicle availability while extending the life of the vehicle. This has also contributed to the reduction in the number of running repairs.

Conclusions

MTA NYC Transit believes that managing with a lean fleet creates an environment in which good fleet planning and strong maintenance programs can flourish. MTA NYC Transit sets an example for other properties seeking to improve operation through improved maintenance practices.

Chicago Transit Authority (CTA)

Fleet Characteristics

In 1994, CTA operated a total fleet of 1,190 cars with an average age of 10.8 years, of which 866 were required for regular scheduled peak service. An additional 78 cars were included in the PVR as gap trains (8.3 percent of PVR), increasing the PVR to 944 cars. CTA reported its spare factor at 20.4 percent. Although CTA has purchased cars recently, the percentage of cars older than 25 years is approximately 13 percent. The entire fleet is in married 2-car consists. All cars can be used on any CTA lines.

Operating Environment

Officials at CTA state that their experience has shown that they cannot consistently meet schedule requirements with a 20 percent spare ratio calculated as defined by the FTA for the Section 15 reporting formula. The agency cites the following operational factors as primary reasons for the current number of spare vehicles: customer service initiatives, weather conditions, decrease in patronage, married cars, and CTA's strong preventive maintenance program. The CTA system is elevated or at-grade with a small section underground in downtown Chicago. This factor requires more spare vehicles because of the severe weather conditions in winters.

CTA has a strong corporate philosophy to limit service delays and to provide cars without graffiti and with functioning heating and air conditioning systems. Implementing these service initiatives requires ready, timely substitution of vehicles. Since most of the system is elevated, gap trains are heavily used to avoid delays that force passengers to wait in the cold for service. Each of CTA's seven routes is provided a full spare consist. Stored along the routes in terminal spare pockets or in the yards, these gap trains are used 70 percent of the time. Moreover, each of the lines has its own designated number of spares for regular maintenance and cleaning. The heavy reliance on gap trains provides a strong argument that these extra trains should be included in the scheduled service.

Another determinant of spare vehicle fleet is ridership levels, which have decreased in recent years. The Green Line has been temporarily out of service because of a major construction project. When it re-opens, however, officials anticipate a return of ridership to former levels, or even an increase in ridership. Over the last 2 years, CTA purchased 256 cars from Morrison Knudson. In light of the recent downturn in ridership, however, agency officials believe that they acted prudently when they did not exercise an option to purchase still more cars. This will allow them time to assess whether the agency needs additional cars.

Maintenance Practices

Essentially, the CTA fleet is much improved in recent years. In an effort to increase vehicle reliability, the agency has decentralized its maintenance operation to the carhouse connected to the line and has discouraged transfers between routes. The agency asserts that while this arrangement may require more cars, in the long run it improves maintenance because the carhouse crews "own" the equipment and are more qualified technically in making repairs on the fleet. The seven routes are served by 12 running maintenance shops, so that some routes have access to and are served by more than one maintenance facility.

The information provided indicates that on average, CTA has 218 cars (18.3 percent of total fleet) out of service daily for inspections, heavy maintenance, running repairs, and the major overhaul program (which alone requires 12 vehicles). Provided that funding is available, mid-life overhauls on those cars purchased in 1981 will begin soon. Because of the married cars, one failure requires the removal of both cars from service, which has affected car availability.

CTA's challenging physical operating environment causes more maintenance than at other systems. Parts of the transit system are at-grade and are ballasted in the median of an expressway. Therefore, the vehicles must contend with debris, salt, and snow on the right-of-way. Chicago's severe weather conditions cause major maintenance issues on the elevated system as well. During heavy snowstorms, for example, door and traction motor problems increase the need for spare vehicles.

Conclusions

CTA has a well-managed fleet and is very aware of the issues facing its system. Without adequate spares, it would be unable to meet the challenges caused by the weather and its older fleet.

Washington Metropolitan Area Transit Authority (WMATA)

Fleet Characteristics

In spite of severe demands on its aging fleet, WMATA is committed to operating with a 20 percent spare ratio. With 764 rail vehicles averaging more than 10 years old, WMATA relies heavily on gap trains in daily service. The entire fleet consists of married pairs. WMATA does not count in its TAF the 50 stored vehicles that are used to fund its ongoing overhaul program or the four vehicles used for revenue collection purposes. WMATA plans to overhaul 70 cars a year and the 50 cars are used to support that program. WMATA officials indicate that the methodology used is correct because without these extra cars, they would not be able to make service.

Operating Environment

Operating in the nation's capital, an urban environment with lines traveling to surrounding suburban communities, WMATA has a major demand for quality transit service in the area. With heavy ridership, WMATA relies on its gap trains. WMATA staff are guided by the motto, "We don't miss trips." To maintain correct headways, reliance on gap trains has become routine; they are used daily. Finally, WMATA, like many other transit systems, does not allow cars in service that have no lights, torn seats, nonfunctioning heating or air conditioning systems, or that are dirty--all of which necessitates the use of gap trains to prevent short service.

Maintenance Practices

WMATA believes that its number of spare vehicles is appropriate for other reasons as well. The entire fleet is married pairs. On average, 118 cars (17 percent of the TAF) are out of service during the daily peak period. Eight percent are attributable to running repairs, primarily because of the older vehicles.

With its overhaul program of vehicles out of service for extensive overhaul periods as well as for frequent scheduled inspections, the agency's service levels would be significantly affected if spare vehicles were restricted.

Conclusions

WMATA believes that there should be a standardized reporting procedure and a formula for determining the spare ratios at each system. WMATA officials urge that the treatment of spares involved in major overhaul programs should be different from spares used for day-to-day repairs only. Because of its location and heavy tourist traffic, WMATA has special concerns that timely and quality service be provided. Establishing realistic spare ratios helps WMATA maintain quality service in this highly visible transit operation.

San Francisco Bay Area Rapid Transit District (BART)

Fleet Characteristics

BART has 590 single car vehicles in its TAF. For the purpose of determining its spare ratio, however, only 575 vehicles are counted: one test car and 14 serious accident cars are deducted. BART requires 453 cars to meet peak scheduled service, which includes four relay or gap trains of 10-car consists--roughly one for each yard. The gap trains are used on average 51.3 times weekly. Peak service also includes seven cars that serve as "instant failure floaters." BART operates an aging fleet with about 74 percent (440 cars) between 18 and 22 years old. The majority of the BART fleet is not compatible and BART management claims this also has an impact on the spare ratio. The fleet consists of three types of cars--type A lead/trail cars, type B mid-consist cars, and type C fully integrated (147 cars). Current restructuring of the BART service plan and the planned extensions may increase flexibility and permit more substitutions for out-of-service cars. Some type A cars may be converted to type B, which will also increase fleet utilization and decrease the need for additional vehicles.

Operating Environment

BART's high spare vehicle requirements are attributable to a number of factors: an aging fleet without an ongoing overhaul program; assignment of specific cars to specific shops (captive fleet) with no allowance for substitution; incompatibility of cars; a strong customer-driven program requiring enough cars in excellent condition to serve transit needs at all times; and finally, the likelihood that more cars will be needed to fund expansions in the near future. BART operates as an elevated, at-grade, and underground system in a moderate climate without the threats and disadvantages of severe weather.

Maintenance Practices

In spring 1994, BART did not have a major overhaul program, although historically, it had overhauled components on an as-needed basis. Currently, the agency is preparing for a major vehicle rehabilitation program for its more than 20-year-old cars. BART reports that it performs inspections on the A/B (lead/trail) cars every 550 hours or 16,115 miles, and on the C cars mid-consist every 600 hours or 17,580 miles. It reports an average of more than 101 cars (17.5 percent of the TAF) out of service during peak service daily, of which 45 are out for running repairs.

In 1990, BART set up the Captive Fleet Program, which divided the total fleet among the four maintenance shops to improve vehicle performance and reduce in-service breakdowns. All repairs on the assigned cars are performed at the shop to which the cars are assigned; these cars are run in the same train, with no mixture of the fleet between shops. Segregating the fleet in this manner has increased the number of spare vehicles required, and supports BART's decision to assign one spare train for each yard.

As part of its customer service initiative, BART removes trains from service when they have offensive graffiti, severely soiled interiors, torn seats (upholstered), or nonworking air conditioning systems, depending on weather conditions. This program also contributes to an increased reliance on spares.

Conclusions

BART's nonintegrated cars make it difficult to survive with a lean fleet, which consists of lead/trail cars and mid-consist cars that cannot be integrated. BART is currently expanding its routes, which will increase its vehicle requirements in the near future.

BART, a 20-year old system, experienced significant growth to reach its current size. Even now, new routes are being added that will require more vehicles if BART maintains its current operating structure. Further, with the implementation of a mid-life overhaul, even more spares will be required. Adjustments for new growth and major programs must be a part of the overall discussion in evaluating spare ratio issues. Finally, with the opening of planned extensions in the near future, additional vehicles will be required. At the very least, these system-specific factors seem to argue in favor of the inclusion of on-line spares as a part of the PVR.

SPECIFIC PROBLEMS OF OLDER HEAVY RAIL SYSTEMS

While operating an old fleet is not a guarantee that more spare vehicles will be required, many systems have experienced significant problems because of aging fleets; these fleets require more maintenance attention because of difficulties in obtaining parts and, particularly, if the cars were not welldesigned initially. The following discussions of the Massachusetts Bay Transportation Authority (MBTA) and the Southeastern Pennsylvania Transportation Authority (SEPTA)--Blue Line provide some insight into the problems with aging fleets and the resulting impact on the number of spare vehicles required.

Massachusetts Bay Transportation Authority (MBTA)

Fleet Characteristics

MBTA, located in the Boston metropolitan area, operates 386 railcars over three routes, in the city and into the surrounding suburban community. MBTA officials report that the Red and Blue Lines operate with a more than 20 percent spare factor. In late 1994, the Red Line operated 196 cars of 1958/1968 vintage with a PVR of 152 vehicles, including approximately three gap trains when there were available cars. The agency indicated that it is currently taking delivery of new cars and will be scrapping the oldest cars on the Red Line shortly thereafter. MBTA anticipates a total operating fleet of 218 Red Line cars of which 174 will be required for peak service, leaving 44 cars as spares. The Blue Line has 70, 16-year-old cars and the Orange Line, a relatively new line built largely to replace the old elevated Orange Line structure, has 120 14-year-old cars. None of the cars on these three lines can be interchanged with each other because of different loading gauges, requiring different equipment.

Operating Environment

MBTA officials report three major factors that drive the need for spare vehicles: the large number of old cars on the Red Line (this will change with the acquisition of new cars); labor unrest, particularly in the maintenance back shops where heavy maintenance is done, which results in a lack of productivity adversely affecting maintenance activities; and the severe winter weather.

Agency officials indicated that they do not put out sufficient Red Line cars to consistently make the actual scheduled service because of maintenance problems. Gap trains, when available, are required to support service. With the new Red Line cars, MBTA expects improved vehicle reliability, which should reduce the need for spare railcars on this line.

Labor issues related to MBTA's current attempts to increase privatization to reduce operating costs have led to labor tension, particularly in the back shops.

Finally, weather conditions in Boston are severe, with a reported 97 inches of snow in 1993. Since all of the rail lines operate above ground, snow and icy conditions significantly impact vehicle availability and cause delays. While the Blue Line operates with a reported 25 percent spare ratio, related in part to the decrease in PVR over the last 4 years, the Orange Line maintains an 18 percent spare ratio.

Maintenance Practices

On average, more than 20 percent of the Red Line fleet is out of service during peak service, a substantial number for running repairs. MBTA says that although it performs inspections more frequently on Red Line cars (at 7,500 miles), this has had a limited impact on the number of running repairs due to the age of the cars. Performance on the Blue and Orange Lines is better, with approximately 12 percent of each fleet out of service for running repairs. Inspections are completed at 8,500 miles for these two lines. While there is no overhaul program in place now, new specifications are being developed for the Blue and Orange Lines.

Conclusions

MBTA is a complicated system with three different lines that cannot be integrated, problematic weather conditions that generate more work, and labor/management relationships that are of some concern. All of these factors contribute to an increased reliance on spare vehicles to maintain adequate service levels. Without the reliance on gap trains to support the Red Line, serious service shortfalls would greatly affect service. With the arrival of the new Red Line cars, MBTA officials were confident that operating performance would improve.

Southeastern Pennsylvania Transportation Authority (SEPTA)--The Blue Line

Fleet Characteristics

SEPTA operates two heavy rail lines: the Orange and the Blue Lines, but the fleets are not interchangeable because of different types of equipment and environment. SEPTA's Blue Line operates on 5-ft, 2 1/4-in. wide gauge track, with cars about 9-ft wide by 55-ft long. SEPTA's Orange Line operates on standard gauge track (4 ft 8 1/2 in.) and uses cars 10-ft wide by 67-ft, 6-in. long. The cars are therefore not interchangeable. Each line has its own fleet and its own maintenance shop. The Orange Line is discussed later in this report. SEPTA's Blue Line cars have had reliability problems since their acquisition in 1960. Their age has accentuated their unreliability. The 35-year-old Blue Line cars are scheduled to be replaced in 1996 with the acquisition of a new fleet of 110 married pairs (220 cars). Eighty-five percent of the fleet is married pairs. SEPTA indicated that the current TAF for the Blue Line is 217 cars, which has been revised downward from the original 270 cars initially purchased. Fourteen cars have been removed pending scrap. The current PVR is 168 cars, providing a spare ratio of 29 percent.

Operating Environment

The Blue Line is SEPTA's most heavily used rapid transit line; it operates largely as an elevated system with portions running as a subway in the central city area. At this time, the Blue Line needs more spare vehicles to consistently meet service requirements. Because most of the cars are married pairs, when cars are removed from service for maintenance or inspections, both cars must be pulled, further reducing car availability. In the past, the Blue Line relied heavily on gap trains, but because of maintenance problems it has not had cars available for stand-by trains. However, when extra cars ever are available, stand-by trains are provided as required.

With a large portion of the system elevated, weather conditions have a profound impact on service. As an example, during the winter of 1994, the Blue Line encountered frozen lines and failed traction motors, which resulted in long service delays. Finally, SEPTA's corporate policy does not permit operation of trains that are dirty or have nonfunctioning heating and fan systems (cars are not equipped with air conditioning). This policy, combined with the fleet's maintenance, repairs, and external operating problems, often limits car availability, even with a 29 percent spare ratio.

Maintenance Practices

Despite frequent inspections and a major overhaul program in the 1980s, at the time of the survey, about 34 percent of the available cars are held from service during peak service each day. Safety inspections are a part of the preventive maintenance program, but, because of the fleet's age, it is difficult to make service when unexpected events arise.

Conclusions

SEPTA officials anticipate that the new cars for the Blue Line will be available within the next couple of years. When these cars are received, the agency anticipates an initial ridership surge, which will require an increase in its peak requirement from 168 to 192 cars, including the use of two gap trains, decreasing its spare ratio to 14.5 percent. With the new ridership initiatives being implemented in coming years, SEPTA expects to exercise an option to purchase more vehicles to keep up with the ridership growth. Given the difficulties that other transit agencies are now facing as a result of vehicle over-purchases, SEPTA management indicates that it will use due caution before exercising its purchase options.

Port Authority Trans-Hudson Corporation (PATH), New York, New York

Fleet Characteristics

PATH operates 342 single cars of an average age of 20.8 years carrying 75,641 weekday passengers between northern New Jersey and Manhattan. The TAF and the PVR of 297 vehicles (including 15 gap cars) have remained stable over the last 5 years. These vehicles are in operation 50 percent of the time each week. PATH reports its spare ratio as 13 percent, including cars scheduled for maintenance. All lead/trailer cars in its fleet are compatible. Of the 342 cars reported, all but 96 are 22 years old or older. The majority of the vehicles were remanufactured between 1984 and 1987.

Operating Environment

PATH is a small interstate heavy rail system operating between Hoboken, Newark, and Jersey City, New Jersey and lower and midtown Manhattan in New York City. Aside from NJ Transit, PATH is the only rail system serving passengers traveling into Manhattan from New Jersey for work, and is heavily used because it is convenient. PATH travels far into Manhattan, up to 33rd Street in midtown, and is a very popular service because passengers can transfer to other lines in the MTA NYC Transit system. Four routes cover approximately 21.1 miles, and each train has seven to eight cars each. PATH officials report that they do not experience problems with weather related maintenance issues as theirs is almost entirely a subway system.

Maintenance Practices

PATH is a well-run system with a very high vehicle availability despite its older fleet. The fleet is subject to inspections every 90 days, which include trucks/converters, doors, propulsion system, batteries, car body, air conditioning system, radio and PA system, lighting, and air systems. In addition, PATH has implemented an overhaul cycle for components that includes doors every 5 to 7 years, air conditioning every 5 to 7 years, trucks every 7 to 8 years, traction motors every 300,000 miles, and gear boxes every 8 years. Only three cars are out of service for overhaul on an average day. The entire fleet was remanufactured a decade ago. As a result of its intense inspection and overhaul program, PATH only experiences from 7 to 14 cars out of service daily due to running repairs at this time, a significant decrease since 1989 when the number of daily running repairs was 57.

Conclusion

Given the inclusion of gap trains and the low number of vehicles out of service for maintenance, PATH officials calculate a low 13 percent spare ratio.

Metropolitan Atlanta Rapid Transit Authority (MARTA)

Fleet Characteristics

MARTA has 240 10-year old vehicles in operation of which 158 railcars are currently required for peak service on two lines. With its vehicle purchase in 1985-86, MARTA made a policy decision to exercise all options on the existing vehicle purchase, significantly increasing its spare ratio to 37 percent. At the time, MARTA was considering an extension and it was more cost effective to buy additional cars at that time. Now that the 7.1-mile extension on the north line is about to open in 1996, PVR will increase to 200 vehicles, decreasing the spare ratio to 20 percent. With yet another 2.3-mile extension expected in the year 2000, MARTA anticipates purchasing more cars to accommodate the planned increase in ridership.

Operating Environment

MARTA also indicated other operational concerns that should be considered when reviewing the need for spare vehicles. The agency's vehicles, officials claimed, have complicated electronics systems that have reduced vehicle reliability. Further, MARTA just implemented a mid-life overhaul program for 14-year-old cars, which will have a significant impact on the number of cars out of service and the need for spare vehicles. All cars will be overhauled at outside facilities. Because of these maintenance issues and new customer service initiatives mandating the removal of cars from service for nonsafety-related passenger amenities, MARTA maintains that it has too few excess vehicles to ensure that it can meet service requirements.

Maintenance Practices

Despite a strong preventive maintenance program inspecting railcars every 60 days, MARTA officials are experiencing maintenance problems with the electronic components in the railcar systems. An average 8 percent of the vehicles are out of service for running repairs daily and another 30 to 40 for heavy maintenance. Maintenance personnel anticipate implementing a major overhaul program to assist in addressing these issues.

Conclusions

MARTA's experience is similar to other properties with unrealized system growth plans and ridership projections. However, with the opening of the new extension, 10 years later, MARTA will be able to operate with a reduced spare fleet.

Metro-Dade (Florida) Transit Agency (Metro-Dade)

Fleet Characteristics

Metro-Dade owns 136 rail vehicles (68 married pairs) of an average age of 10 years, purchased in 1984 when the system opened and which operate on one elevated line 21.5 miles long. The current peak vehicle requirement is 76 cars.

Operating Environment

Metro-Dade was built to cover 21 miles with an average daily ridership of 200,000. The rail fleet was purchased to accommodate a 1970s ridership projection. It was based on assumptions that were reasonable at the time, i.e., increase in the price of gas, employment growth, low parking rates, and a stable parking supply, but as seems to be common in the industry, the ridership projections have not been achieved. Metro-Dade had leased four vehicles to Los Angeles (since returned) to test on its system, but there are no plans to sell or otherwise reduce the fleet because of anticipated ridership increases associated with expansions to be completed in the future. In addition, every 90 days, 8 to 10 married pairs are put into inactive storage. The agency does not want to rotate the entire spare fleet in and out of storage because it does not have adequate storage space and must use almost all cars for special occasions. For example, 120 cars are required every New Year's Day for the Orange Bowl parade.

In the near future, Metro-Dade plans extensions, which will increase the PVR to 102 vehicles, reducing the spare factor substantially. When the extensions open, a significant ridership increase is expected.

Maintenance Practices

Metro-Dade uses a time-based inspection cycle, bringing cars in every 45 and 180 days for preventive maintenance inspections. On average, 20 cars are held out of service for running repairs during peak service. In 1995, Metro-Dade will implement its first major overhaul program for its 10-year-old fleet.

Conclusion

Metro-Dade's experience seems to be another common industry example where both special event needs require almost all vehicles and of unrealized growth projections, which officials fully expect to realize when current planned expansions are completed and significant ridership increases are achieved.

Port Authority Transit Corporation (PATCO), Lindenwold, New Jersey (With SEPTA--Orange Line)

Fleet Characteristics

Because of their similarities, these two agencies are being examined together. The SEPTA Broad Street Orange Line operates 125 13-year-old Kawasaki single cars from its Fern Rock terminus over 11 miles of track into South Philadelphia. With a 1993 PVR of 113 vehicles, it is a heavily used subway line, carrying 26 million people annually. PATCO carries 11.2 million people annually on a fleet of 121 20-year-old cars, operated in 6-car consists, of which 102 cars are required for peak scheduled service. A majority of the cars are married pairs and cannot be disconnected in service. The SEPTA Broad Street cars are all single units, while PATCO's fleet is 21 percent single cars and 79 percent married pairs.

Operating Environment

SEPTA's Broad Street Orange Line and the PATCO system both manage with few excess spare vehicles. SEPTA's Broad Street reported a 10 percent spare ratio and PATCO a 15 percent spare ratio. The Broad Street Orange Line is a heavily used subway line running from the northern part of the city of Philadelphia through Center City to South Philadelphia. PATCO, largely a suburban line, operates with morning and evening peak load lines--from southern New Jersey also into Center City, Philadelphia. These two lines, roughly the same size and operating in adjacent territories, have similar characteristics: each operates quality service with fairly low spare ratios and each rarely misses service.

Maintenance Practices

The reason that these fleets perform as well as they do is because of their strong preventive maintenance programs.

SEPTA Broad Street Orange Line--The maintenance philosophy at the Orange Line shop centers on preventive maintenance. The 13-year old cars have undergone intense scheduled maintenance from the time they arrived on the property. Documentation of procedures and materials was available from the day of delivery, and the shop has had consistently good engineering support all along. A plan for a formal light overhaul program was begun only 3 years after the cars were actually on the property. The maintenance staff documented maintenance requirements over a 2-year period and then developed a 5-year "light overhaul program" that included a visual inspection of all parts; changes were made as required. Motors were cleaned out, new wheels were put on trains that needed them, rubber mounts were changed, heavy service was done on the traction motors and drive units, and cosmetic improvements were made, such as repairing light fixtures and seats if needed. The cars are now halfway through a standard mid-life overhaul program.

In response to the survey, Broad Street personnel indicated that they hold only 11 cars out of service during peak period, and none are held for running repairs. The shop also maintains an aggressive inspection schedule; cars are inspected every 14 days, 3 months, 2 years, and 5 years, when they undergo the unit mini-overhaul discussed above. SEPTA's policy not to run cars with nonfunctioning air conditioning, heating, or PA systems is not a problem because these systems are maintained routinely on this line. The maintenance staff tracks and documents all failures so that repeat failures are identified early and can be resolved quickly.

Port Authority Transit Corporation (PATCO)--Although it has a different maintenance philosophy, PATCO also manages its operation with limited spares. PATCO does not include gap trains in its PVR, but it does use an extra train when available to assure on-time departure. If a train cannot continue in service because of deficient passenger amenities or failure of a safety-sensitive system, that train is removed from service.

Only 13 cars are held out of service on an average day, of which two are held out for running repairs. Of its 121-car fleet, 75 of the cars are 25 years old and the balance are 13 years old.

The agency believes that performance reliability is largely a function of car design. A major defect can adversely impact long-term performance. At PATCO, the oldest cars were built in the 1960s and were of the first generation to have automatic train operation and control. These sophisticated cars have provided a high level of performance over the years. Problems encountered with the electrical/mechanical devices have been virtually eliminated with an overhaul program in which cars are rewired to accommodate some of the upgrades that were standard with the 1980 fleet.

The agency commented that, despite this sophistication, the cars are relatively easy to maintain, but require skilled troubleshooters since on-board diagnostics are not employed. To facilitate proper maintenance, given the heavy use of the fleet during the peak periods, trains are reduced to two-car consists during the base, so that the fleet does not accumulate excessive mileage requiring more frequent inspections. The location of the maintenance facility at a terminal has played an important part in quickly returning cars to service.

Although PATCO officials acknowledge that they are able to manage with a tight fleet, they caution against too lean a spare factor, citing experience in the late 1970s before the additional 46 cars were acquired. At that time, a great deal of maintenance was deferred. Shop facilities and maintenance manpower were under-used. Ultimately, this "make service at all costs" attitude contributed to more problems than necessary. Each system must assess its own needs and unique characteristics in arriving at an appropriate and cost-efficient spare factor.

Conclusions

Both of these systems have been nurtured to operate efficiently with low spare ratios. SEPTA's Broad Street Orange Line railcars are very simple mechanically and have been well maintained. PATCO has implemented a maintenance program to ensure that its railcars perform well. Despite fiscal restraints, these systems illustrate how creative agency staff can develop programmatic strategies to manage their fleets well and control costs.

Greater Cleveland Regional Transit Authority (GCRTA)

Fleet Characteristics

With a total fleet of 60 heavy rail vehicles that are 11 years old, Cleveland requires only 30 vehicles to meet current peak service. These cars operate in two- or three-car consists. The system operates above ground except at the underground airport station. Forty of the cars are single unit, single end, and independent, and are normally operated as 20 coupled pairs. The balance of the fleet is individual cars. Both types can be and are coupled in any order. GCRTA has no married pairs.

Operating Environment

Although ridership has remained steady over the last 5 years, GCRTA has undergone a major ridership decline during the previous decade when businesses vacated the city. Most of the ridership is on the heavy rail line and GCRTA officials do not quote a spare ratio because of the many excess vehicles they have. However, the agency reports that throughout the year it does provide service for special events at the ballpark, allowing it to use these vehicles and recoup some costs. Indeed, without the ability to add substantially more trains, GCRTA would not be able to serve the special event ridership. To attract additional daily riders, GCRTA has a passenger amenities program requiring that trains be held from service for cleanliness, graffiti, torn seats, air conditioning, and heat.

Maintenance Practices

GCRTA reports 17 cars out of service daily, of which five are running repairs and some of these are attributable to the light rail system. Inspections are performed at 5,000 miles and GCRTA officials report that they do not have an overhaul program for the heavy rail vehicles at this time.

Conclusion

GCRTA officials believe that uniform definitions and formulas for the calculation of spare ratios would provide a data base against which each agency could compare and evaluate itself.

CANADIAN HEAVY RAIL SYSTEMS

Montreal Urban Community Transit Corporation

Fleet Characteristics

The Montreal system is a rapid transit line with a fleet of 759 vehicles permanently married consisting of three-car consists in groups of three, six, and nine cars and a reported PVR of 565 cars operating on four routes. Approximately 55 percent of the fleet is 17 years of age and the remaining cars are 27 years of age. In responding to the survey, Montreal did not provide a spare ratio. Although the data indicate that Montreal has many spare vehicles, a review of the agency's operating environment suggests that the agency has little cushion to make service due to heavy maintenance requirements. Like other transit agencies, Montreal sets aside extra "reserve" trains on two of the lines to augment peak service. Stored at the end of the lines, these two trains are not counted in the peak service requirement.

The three-car units are not separated except in extraordinary circumstances as the cars share major component systems. Although the cars can technically run on all lines, there are some commercial constraints. For example, Montreal has a special project in place on one line to install Telecite, special equipment for public advertising. Due to this special signage, Montreal does not run the older railcars on that line.

Operating Environment

Montreal's system serves both commuters and a large tourist population; this leads to ridership fluctuations. Every attempt is made to complete maintenance on all three cars of a consist simultaneously. However, this is not always possible. When one car fails, the entire three-car group must be removed from service. Given this significant maintenance issue, the current spare vehicles do not provide an adequate cushion for the operation.

Maintenance Practices

Agency staff report that they can run with few spare vehicles in part because of their well-developed maintenance practices. All cars are inspected every 9000 km (approximately 6,000 mi). Other than the body overhaul discussed above, Montreal does not have a mechanical mid-life overhaul program, although major heavy maintenance repairs are performed regularly. Montreal officials reported that in 1993, on average, they held 147 cars from service during daily peak service as follows:

Inspections	33
Heavy Maintenance	12
Running Repairs	48
Vehicle Overhaul (body work only)	39
Quality Control	15

Although the major body overhaul program is now complete, the agency reports that the program took more than 2 years to complete during which time each car was out of service for more than 10 weeks. However, as soon as the program was completed, the agency increased service on one of its lines, further increasing the need for vehicles.

Montreal has two classes of cars: the first class consists of 336 cars, which are 27 years old and dedicated to one line. These cars are maintained at one facility, the Beaugrand shop. Montreal officials believe that this helps their maintenance program because all personnel assigned to the shop are highly conversant with and technically qualified on that particular fleet. The second class of cars is maintained at the Youville shop.

Conclusion

The Montreal experience illustrates the impact of operating multi-car units on daily vehicle availability. These three-car units have adversely affected this system's ability to operate with limited spares. Even if a defect is limited to only one car, the impact on the overall fleet is significant. Despite its enhanced maintenance program, Montreal requires a large number of vehicles to support its operation.

Toronto Transit Commission (TTC)

Fleet Characteristics

TTC responded for its Rapid Transit division, subway, and light rail or street car lines. The rapid transit line is the newest line and uses intermediate capacity cars with a linear induction motor system similar to BC Transit in Vancouver; these cars cannot be integrated with the other systems. For the purposes of discussion, the information provided in this section will be limited to the subway system to illustrate how TTC quantifies and allocates its vehicles.

TTC operates a fleet of 622 married pair subway vehicles. The agency reported that it does not uncouple these cars unless major repairs are required. The TAF has varied little in recent years, but the PVR has declined significantly since the 1989 high of 775 vehicles. In 1993, 492 vehicles were required for peak service, of which two percent were gap trains. TTC reports that the 622 subway vehicles range in age from 4 to 32 years of age, and that the agency's spare ratio is 15 percent.

Operating Environment

Although the data show that the TTC has 130 spare vehicles (a 26 percent spare ratio if calculated using the FTA formula), TTC officials indicate that this is not really the case. TTC states that it operates with a 15 percent spare ratio. Maintenance staff estimate that 93 cars are used to replace cars in budgeted and scheduled maintenance, as well as those in running repairs. The balance, designated as "surplus" cars, are scheduled to be retired. These surplus cars are also used to support unanticipated major work, such as major accidents and fleetwide defects. The agency contends that these older cars should not be regarded as typical spare vehicles because they are not put in service except in extraordinary circumstances. For example, some of these cars are now being used to support a program installing a door warning system for the visually impaired.

External conditions are an important factor in TTC's operating program. Like other northern systems, Toronto experiences harsh weather conditions, aggravated by the fact that its cars must operate at-grade as well as underground, and most cars are stored outside. In addition, there are several grades and curvatures on the lines that create substantial wear and tear on the cars.

Maintenance Practices

In spite of the adverse conditions, TTC is able to maintain a relatively low spare ratio; the vehicle maintenance spare ratio is calculated by the agency, based on previous experience, on a recently adopted maintenance philosophy, and on an "opportunistic maintenance" program currently being put into practice. Opportunistic maintenance entails remanufacturing and changing components before failure occurs. While TTC still maintains a rigorous inspection program (every 15,000 miles) and carries out special project work, it is trying to limit running repairs and in-service failures. During peak service, the agency reports an average of 18 cars out of service for maintenance and an average of 50 to 60 running repairs daily for the fleet.

TTC has abandoned its mid-life overhaul program. With implementation of the new component replace/repair program, the system is experiencing increased vehicle availability as well as extended vehicle life. TTC is in the process of establishing life cycles for various components through data accumulated from maintenance experience. Various components such as air brakes, power connectors, air conditioning systems and compressors, control equipment, and motors will be taken out and remanufactured. When a car is brought in for inspection or other any reason, all other items are inspected and repaired if necessary. TTC has moved from a "look, see, and repair" philosophy to "change all units before they fail." These new maintenance procedures have an added benefit of increasing productivity as well.

While TTC officials report that they will remove trains from service for nonsafety related passenger amenities, they will do so only if substitute cars are available. They indicated that their number one commitment is to service and that passenger amenities do not warrant interrupting service.

Conclusions

TTC operates a well-run fleet without reliance on excessive spare vehicles. Although the number of spare vehicles appears to be significant, it actually represents good fleet planning especially if the agency does not rely on the old vehicles. A specific number of cars for maintenance seems to be a good idea if the system does not use the stored vehicles to supplement routine or light maintenance.

British Columbia Rapid Transit Co. (BC Transit)

Fleet Characteristics

Established in 1986, BC Transit, a subsidiary of the British Columbia Transport Co., describes itself as an advanced light rapid transit system. BC Transit operates both underground and as an elevated system. With a fleet of 130 fully automated vehicles with an average age of 7.3 years, the fleet operates without an on-board crew. The entire operation is managed from a control center housed at the central facility located midline, which also contains office headquarters and the maintenance shop and yard. BC Transit reports that in 1993, it required 116 cars for peak service (including one gap train), but scheduled service increased to 120 cars with the opening of an expansion in April 1994. Although 20 additional cars are on order, the system presently operates with only 10 spare cars. However, the agency reports that it makes service 99.6 percent of the time.

Operating Environment

Several key factors allow this system to operate as it does with such a limited spare ratio. First, it is a very young system with state-of-the-art equipment and the weather is mild year-round. Most of the cars are only 8 years old, with the last 16 being purchased just 3 years ago. In addition to these clear advantages, BC Transit has a strong maintenance program. BC Transit does not face some of the problems noted for other systems. Although the agency operates four-car trains consisting of two married pairs, cars can be uncoupled from the control center in a matter of minutes. And although cars in service are seldom uncoupled, this operating ability gives the agency a significant advantage when unserviceable cars need to be removed.

Maintenance Practices

Only six cars are held from service for daily inspections. Every 10,000 miles, heavy maintenance is performed on the cars. All running repairs are performed off-peak and are completed prior to the next peak period. Although the fleet is very young, the maintenance personnel report that they perform overhauls on the major subsystems every 7 years, and replace brakes every year and motors every 3 to 4 years.

Conclusions

BC Transit operates with a very lean spare ratio. The agency demonstrates the quality of service that can be provided when all the circumstances are working in a system's favor.

LIGHT RAIL SYSTEMS

Light rail vehicle (LRV) systems experience different problems from heavy rail and commuter systems. Most must contend with street traffic, pedestrians, traffic signals, and cars causing accidents by coming too close to the trains. Yet they have been a part of the American scenery over the last century. Because of the need to conserve capital dollars, many agencies are revitalizing older light rail systems while others are building light rail systems instead of more expensive subway operations.

Weather and street conditions, such as potholes and sinking streets, may impact service operations as with other at-grade systems. The following profiles illustrate the system-specific variables that impact light rail systems generally.

Massachusetts Bay Transportation Authority (MBTA)

Fleet Characteristics

MBTA operates a 32.4-mile light rail line as an integral part of its rail operating system in the metropolitan Boston area with 180 light rail single cars of an average age of 12.6 years. MBTA officials indicate that they operate two types of cars that cannot be integrated. This LRV system operates two-car consists in peak service and on Saturdays due to heavy riding. Of the 180 cars in the TAF, only 141 cars are required for peak service, which has increased in recent years because of heavy ridership. Management also reports that it uses gap trains to support service, with 3.5 percent of the PVR used in the morning and 5.7 percent of the PVR (a total of eight railcars) used in the afternoon. The agency reports a 31 percent spare ratio.

Operating Environment

The four lines constituting the light rail system operate on the street, at grade crossings, and on a dedicated right-of-way. Only one line operates solely on a dedicated right-of-way; two lines operate at grade crossings with some automobile integration at the terminals; and the remaining lines operate down the middle of the street. Those lines operating in the street or at grade crossings must stop for traffic signals to allow traffic to pass and as a result, incur delays when traffic is heavy.

Like other northeastern cities, Boston has major problems with its severe winter weather, which can occasionally impact service. Management acknowledges that it operates with a high spare ratio, but indicates that it requires many spare vehicles because the nearly 20-year old Boeing fleet has high maintenance needs and also because the street operation of its fleet generates maintenance due to minor accidents with automobiles. Ridership on the light rail system has increased recently on lines that serve civic and fine arts institutions, Fenway Park, and various universities and hospitals.

Maintenance Practices

MBTA management officials report that operating a fleet in which more than one-half of the vehicles are 20 years old requires extensive maintenance. While the agency plans to retire portions of the fleet in 1999 with the acquisition of 100 low-floor vehicles, it must support these old vehicles to ensure availability of service until then. On average, MBTA reported 17 cars (9.4 percent of the TAF) out of service daily for running repairs. Roadcalls also impact vehicle availability--the agency reports a 2,622-mile mean distance between failures, which is a significant improvement over the last 5 years when that figure was reported to be 1,574 miles. Inspections are performed every 3,000 miles on the fleet and every 5,000 miles on the remaining cars. Currently, there is no overhaul program in place but the agency reports that it is seeking authorization to overhaul specific cars.

Conclusions

The light rail system is an integral part of the Boston multimodal system. Management indicates that the spare ratio must accommodate the fluctuations in ridership that this system encounters.

San Francisco Municipal Railway (MUNI)

Fleet Characteristics

MUNI operates 14-year-old Boeing Vertol single car LRVs, generally in two-car consists, within the City of San Francisco. Of the 126 vehicles, 101 are required for peak vehicle service. The TAF and PVR have remained relatively constant over the last 5 years. The agency did not provide a spare ratio and indicated that for the last 18 months, it has had difficulty in meeting peak demand due to poor performance and current maintenance practices. A small fleet of new cars is being acquired, which should reduce MUNI's dependency on the Boeing LRVs.

Operating Environment

This light rail system operates over the hilly terrain of San Francisco and carries both commuters and tourists. Even with mild weather, MUNI officials report that they cannot meet service requirements. The hills of San Francisco generate a great deal of maintenance work for the fleet.

Maintenance Practices

On average, 19 railcars are out of service daily, of which 13 are for running repairs, three for parts not available, and one for vehicle overhaul. Maintenance personnel inspect vehicles every 7 days and, therefore, every 6,000 miles; cab signals are inspected every 6,000 miles. Nonetheless, vehicle reliability continues to be inadequate, generating excessive roadcalls.

Conclusions

San Francisco has many maintenance problems related to its LRVs in operation. However, MUNI officials stated that a common spare ratio for light rail transit systems might be appropriate, provided that it is based on peak demand and overall fleet maintainability and reliability.

San Diego Trolley, Inc.

Fleet Characteristics

San Diego Trolley, Inc., located in Southern California, operates a fleet of 71 light railcars, ranging in age from 4 to 13 years, while 56 are required for peak service. All the vehicles are single units made by SIEMENS Duewag and are generally run in three-car consists. The agency reported a 16.9 percent spare ratio and does not include gap trains in the PVR. However, maintenance personnel indicate that three cars are kept available for spares.

Operating Environment

A small system, San Diego Trolley reports that its ridership has decreased over the last 18 months, continuing a pattern of decline over the past 5 years, primarily as a result of the loss of employment that has plagued Southern California in recent years. But, unlike other systems, the agency reports heavy Sunday riding, which is related to tourist ridership on the southern line that travels to Mexico.

San Diego anticipates opening three new extensions before the end of the decade. The current TAF is 71 cars, and the agency began taking delivery of an additional 30 cars in 1995 and will add 22 more cars to support these expansions, later.

Management acknowledges that there will be extra cars until the expansions are opened and is considering rotating the fleet in and out of storage to reduce its spare ratio. Cars are held from service for nonfunctioning air conditioning systems, but this policy does not impact the number of spare vehicles required.

Maintenance Practices

With a relatively young fleet and mild weather, the expectation is that the system would be well run. San Diego maintenance officials stated that they permit 11 railcars out of service for maintenance issues daily. Of the 11, five are out for running repairs, two for heavy maintenance, and two for overhaul. Currently, this agency went to time-based inspection cycles and regularly inspects vehicles 7 days a week, on a frequent basis (i.e., daily to monthly). In addition, San Diego reports an overhaul program every 3 years where defective components are replaced.

Conclusions

San Diego believes that a 16.9 percent spare ratio is satisfactory for its system but acknowledges that other transit agencies may require more spares. Management believes that more analysis of the issues would be desirable.

Port Authority of Allegheny County (PA Transit)

Fleet Characteristics

PA Transit operates 59 single cars in a three-line light rail system in Pittsburgh, Pennsylvania over 29.3 miles. Originally, PA Transit operated a fourth line, which has been closed for rehabilitation, and retired the cars from on-line service, reducing the fleet from 71 to 59 vehicles. Four of the 59 cars are 47 years old and the remaining 55 are 9 years old. When the line is reopened in 1997, new vehicles will be procured. Peak service requires 43 railcars; three gap trains are included in the PVR. The agency reports a 28 percent spare ratio, which it has determined by tallying those vehicles it requires for special needs. PA Transit officials indicate that the agency allows 8.4 percent of its vehicles for overhaul, 6.7 percent for maintenance inspection, and counts the remaining 12 percent as spares.

Operating Environment

Pittsburgh is a large urban center that relies on the light rail system to transport workers to the central business area. PA Transit operates in severe weather and therefore experiences weather related problems with its fleet. In addition, PA Transit reports major maintenance problems with the fleet. A design problem with the gearbox and propulsion system has led to a high percentage of vehicles being held from service and now requires a fleetwide modification. Until all modifications are completed, all available spares are needed to support service.

Conclusions

PA Transit illustrates some of the issues that arise with fluctuations in the PVR and its impact on the need for spare vehicles. PA Transit retired part of the fleet because a line was closed for rehabilitation, nevertheless, it was unable to reduce its fleet size substantially because of service defects with its younger fleet. To operate without a sufficient cushion was not prudent because a high percentage of the vehicles were out of service regularly for a passenger amenity program that checked cars for heat and air conditioning. Coupled with often severe weather conditions in the Pittsburgh area, fewer spare cars may well have affected the ability to make service regularly.

Management agrees there is a need to address the maintenance issue, but because of the overall car design (gearbox) problem, a complete reconstruction may not be possible. Thus, a flexible spare ratio may always be required to ensure high quality service.

Greater Cleveland Regional Transit Authority (GCRTA)

Fleet Characteristics

GCRTA operates a light rail line, covering 26.7 miles with 48 double-ended light rail vehicles that are 14 years old. During peak service, Cleveland uses two-car consists, which are reduced to only one car in nonpeak hours. The trolley system has a dedicated right-of-way, but must stop at crossings for automobiles. Of the 48 cars in the TAF, only 24 are required for peak service.

Operating Environment

GCRTA officials indicate that this light rail system has experienced significant ridership reductions over the last 15 years. In 1980, when the original vehicles were purchased, Shaker Heights, the community in which this system operates, required Cleveland to purchase 4,000 seats, equivalent to 48 cars. However, over the last decade, with the relocation of major businesses to the suburbs, the ridership has significantly declined. In 1993, the PVR of 24 LRV cars had further decreased from a high of 30 vehicles in 1991. In addition, a planned extension was significantly delayed, but it is now scheduled to open in July 1996. This extension will require an additional 6 to 8 cars for scheduled service.

GCRTA's LRV system operates on a dedicated right-of-way, all above ground. Like other LRV systems in the north, GCRTA does experience severe weather that impacts service to allow for snow and ice removal and to repair its catenary. GCRTA staff also indicate that they need the spare vehicles to support high peaks associated with special events at the ball field, which require additional vehicles about 100 days per year. The agency must use all available cars to provide for the heavy ridership to those special events. Because of this unique requirement, it does not warehouse vehicles, but uses them on a regular basis. GCRTA also reports that the corporate policy requires removal of cars from service for nonsafety related passenger amenity defects.

Maintenance Practices

GCRTA reports some maintenance problems that affect the number of cars required to manage its fleet. The agency is currently experiencing problems with the LRV Chopper ventilation system and is undergoing a fleet retrofit for the gearbox. These issues have contributed to increased roadcalls and maintenance requirements, as reflected in the mean distance between failures rate of 1,533.7 miles. GCRTA maintenance personnel report a strong preventive maintenance program with minor inspections completed every 30 days/3,000 miles and a major inspection completed every 35 days/5,000 miles. In addition, the light rail vehicles are currently undergoing an overhaul, which is done every 4 years.

Conclusions

GCRTA's experience illustrates how changing economic and demographic conditions can radically affect vehicle requirements. In this case, the vehicles were purchased in response to a definitive need. The need was reduced when the entire business and economic climate changed, which resulted in excess vehicles. However, GCRTA has found an alternative use for the vehicles with the extensive use of the fleet to support special events at the ball field; this has offset some of the operating costs incurred through managing an excess spare vehicle fleet.

Toronto Transit Commission (TTC)

Fleet Characteristics

Included in its integrated bus/rail operations, TTC also operates a 125.4-mile light rail system in the greater Toronto area. This system consists of 267 light rail vehicles (street cars) operated as individual cars throughout the streets of Toronto. Of the 267 LRVs, 183 are required for peak service. The TTC management team reports that the spare ratio for its fleet is 12 percent. However, 15 percent of the vehicles are set aside for scheduled maintenance and are not counted as spares.

Operating Environment

Toronto has mild summers and severe winters with snow and ice on the streets, which increases maintenance requirements. Street cars are usually full and stop at every corner. The agency states that the spare ratio is influenced by its policy not to send out dirty vehicles, or those that have torn seats and nonworking air conditioning or heating systems.

Maintenance Practices

Despite the age of the fleet and Toronto's weather, TTC's LRVs have a good performance record. TTC officials do not report any vehicles held from service during peak service. The inspection cycle is frequent with routine and safety inspections performed every 5,400 miles. The overhaul program requires rehabilitation of major components, such as wheels, trucks, traction motors, and electronic assemblies every 4 years. Compressors and air dryers are overhauled every 2 years. Finally, all LRV car bodies are overhauled and painted every 10 years.

Conclusion

TTC management believes that uniform definitions and formulas for the calculation of spare ratios would provide a data base against which each agency could compare and evaluate its operation.

COMMUTER RAIL SYSTEMS

There is a growing reliance on commuter rail services in the United States as riders look for alternative means of getting to work in the central business district. These systems have primarily grown out of old private railway networks, which were assumed by municipalities when these companies began to fail.

Commuter rail passengers are different from those served by the heavy rail and light rail systems nationwide. These passengers demand quality, on-time service, and a seat, and will return to automobile travel if they are unsatisfied. Thus, commuter rail operators are highly motivated to provide safe, ontime, and high-quality service. The operating environment is different from other types of service largely because the service is peak-oriented, going into the business district in the morning and returning in the evening. As a result, commuter systems have more time during the day to perform maintenance activities and to improve the aesthetics of the vehicle.

Maintenance requirements may be different depending on the type of vehicles used. Diesel locomotives and coaches require less maintenance than the electric self-propelled LRV and multiple-unit (MU) trains. The need for spare vehicles is significantly less than for heavy and light rail systems. Indeed, the spare ratios for these systems support this view.

MTA Long Island Rail Road (MTA LIRR)

Fleet Characteristics

MTA LIRR, the nation's largest commuter rail service, operates 11 lines with a fleet of 932 MU electric cars, 177 diesel haul coaches, 51 locomotives, and 14 power units. In addition, MTA LIRR recently purchased 10 bi-level diesel hauled coaches, which can be operated on the third rail. The spare ratio is calculated separately for each fleet subset.

The MU electric cars, which provide most of the service, can be integrated with each other, but obviously not with the diesel push/pull coaches.

MTA LIRR reports that it does not use gap or extra trains at any time because they simply do not have available cars. The agency reports a 12.2 percent spare ratio. For example, MTA LIRR has 932 MU electric coaches and requires 818 coaches to meet scheduled service. Using the FTA Section 15 recordkeeping definition, the spare ratio would be calculated at 13.9 percent. The spare ratio would be substantially higher for the locomotives and the 39-year-old diesel haul coaches, but they serve only a minor part of peak service.

Operating Environment

The key issue for MTA LIRR is the physical operating environment. The agency cannot run diesels into New York City, but on certain lines, only diesels can be run, so those coaches must be concentrated in specific areas. Because most of MTA LIRR's weekday service goes into New York City, the diesels cannot be used to augment the MU fleet. Since much of the system is at grade, weather conditions adversely affect performance as well. Finally, with such a low spare factor, MTA LIRR states that it is sometimes forced to run short consists; however, it does not miss service.

According to its response to the questionnaire, MTA LIRR is barely able to handle the service demands with the limited number of spare MU electric vehicles. It runs every vehicle and, despite corporate policy requiring otherwise, sometimes does not pull cars from service immediately if the air conditioning or heating does not work, but will wait until the train reaches the end of the line.

Maintenance Practices

MTA LIRR has a strong preventive maintenance (PM) program with regular inspections on a short cycle and a life-cycle overhaul program at 2, 4, 6, 8, 10, and 12 years. This aggressive PM program limits in-service breakdowns. The information provided indicates that on average, there are 48 MU cars out of service for running repairs daily--roughly 5 percent of the total fleet. There is currently no major overhaul program for diesel coaches because of plans to purchase new equipment.

Conclusions

Commuter rail services typically operate with fewer spare vehicles than rapid transit systems, but report many of the same problems in managing with limited spare vehicles. Despite many challenges, MTA LIRR operates with a lean fleet. Because of its size, MTA LIRR has a higher peak-to-base ratio than other properties, but still has available time between peaks to perform routine repairs.

METRA (Chicago)

Fleet Characteristics

METRA, a Chicago commuter rail service, operates a lean fleet maintaining a reported spare ratio of 3.5 percent. The total fleet and PVR reported for 1993 are as follows:

	Total Fleet	PVR
Locomotive	130	123
Coaches	686	662
MU Electric	165	145

The bi-level coaches range in age from 14 to 44 years of age, the MU electric cars between 14 and 23 years, and the locomotives are under 20 years old, with 30 under 2 years of age. METRA officials state that the agency does not use gap or extra trains during peak service. The maintenance officials indicated they run everything they can and experience few, if any, in-service breakdowns. Only 25 cars are held from service during peak period for all reasons--including one car for running repairs and 15 for inspection and major overhaul.

Operating Environment

METRA officials acknowledge the difficulties of operating under such tight restraints but indicate that they have no choice. Corporate policy is to provide every passenger with a seat and because they lack sufficient equipment to meet ridership demands, they must ensure that all available equipment is not only ready for service but will stay in service.

Although severe weather is a major problem for METRA and can have a devastating impact on service, the agency has managed to control the impact through innovative and diligent maintenance practices. The agency lost many traction motors because of the snow during the winter of 1993-1994. After some delays, the problem was managed by converting some of the MU electric coaches to trailer cars, running them without propulsion.

Maintenance Practices

One factor that helps METRA is that the entire fleet is composed of single cars, which helps to limit the number of cars out of service. Agency staff report that all they need do is uncouple a single car and the rest of the consist remains in service. The staff also cite strong maintenance procedures and practices as the foundation of their success. Inspections are performed daily, every 45 days, quarterly, semi-annually, annually, and biennially. METRA officials do not hold cars out of service for lack of parts because they maintain a sufficient inventory of proper components so that cars can be put back into service quickly. For example, METRA keeps 68 spare traction motors available for 165 coaches. Therefore, if any METRA car loses a motor during the day, a new motor can and will be installed by the close of the day. The balance of the consist can remain in service.

In addition, METRA has made great strides in eliminating some maintenance issues, that plague other properties through improved maintenance practices. As an example, it has virtually eliminated problems with air brakes. Problems are identified during daily inspections, and repairs are made quickly.

Although severe weather can impact service, METRA's extensive pre-weather (winter/summer) program, which includes everything from seal to proper motor maintenance, helps the agency to operate despite weather conditions. As a result, during the summer of 1993, more than 230 trains ran with virtually no equipment failures. The agency stated that on a bad day, it would have no more than two breakdowns. The in-house major overhaul program also plays a significant role in maintaining the fleet. All locomotives are overhauled every 10 years and the coaches every 15 years. The objective of the overhaul program is not only to extend the life of the vehicle but also to reduce the maintenance required to run the fleet in the interim.

Finally, METRA has a strong maintenance staff with excellent experience in electrical components and in performing overhauls. The hourly personnel are equally well trained; they must have a journeyman card before they are hired. Specific vehicles are owned by a particular location so that the staff has the opportunity to know the vehicle well and become highly experienced in maintaining it. Despite high fleet age, METRA is able to keep its fleet running with few problems.

Conclusions

METRA's positive program could provide an example for other agencies that are looking for strategies to improve fleet performance. METRA's accomplishments underscore the view that rail systems can operate well with a lean spare ratio, provided there is a strong maintenance program at the foundation and a highly motivated corporate team.

New Jersey Transit Corporation (NJ Transit)

Fleet Characteristics

NJ Transit reports a total active fleet of 715 cars, which consists of 415 coaches and 300 MU electric vehicles against a PVR of 582 vehicles, plus 80 locomotives. NJ Transit reports a spare ratio of 20 percent. Cars out of service in excess of 30 days are excluded from this count.

Operational Environment

NJ Transit operates the state's Commuter Rail Network with 598 daily trains, with 161 stations in 137 communities statewide.

The rail system's 12 lines are grouped into three divisions: Hoboken Division (which includes lines operating to and from Hoboken Terminal on the Morris & Essex, Main/Bergen, Pascack Valley, and Boonton Lines); Newark Division (which includes the Northeast Corridor, North Jersey Coast and Raritan Valley Lines operating from Newark Penn Station, Hoboken Terminal, and New York Penn Station); and the Atlantic City Rail Line (which operates between the seaside resort, Philadelphia, and points in between). NJ Transit also runs service to and from points in New York on the Pascack Valley and Port Jervis Lines under contract with the Metropolitan Transportation Authority.

The operational environment is limited due to the fact that push-pull coaches and electric MU cars cannot be intermingled and diesel locomotive service is restricted from operating into New York Penn Station. Also, 65 percent of the peak runs make two trips, which increases the possibility of in-service failures despite extensive preventive maintenance and overhaul programs.

Maintenance Practices

The policy of NJ Transit is to attain the highest possible rail vehicle availability, at the least possible cost, while maintaining safe and reliable rail equipment. To ensure maximum use of each vehicle during its useful life, NJ Transit has designed daily and periodic inspection procedures to ensure continued high performance. These procedures are a combination of all pertinent Federal Railroad Administration (FRA) regulations, original equipment manufacturer's recommendations, and experience.

NJ Transit practices preventive maintenance on all vehicles to decrease the number of unscheduled repairs. When repairs are required, they are categorized as either:

- Running Repairs: Can be performed without removing the vehicle from service-less than 30 minutes without special tools and equipment.

- Light Repairs: Must be performed in a facility, but can be accomplished within service needs between a.m. and p.m. rush.
- Heavy Repairs: Keep a vehicle out of service for 24 hours or longer and require special equipment, such as a crane or drop table.

All repairs are made in accordance with NJ Transit Rail's standard maintenance procedures. NJ Transit holds cars out of service for non-safety related repairs, such as air conditioning and cleaning, and is mandated to hold cars from service for toilet repairs.

There are many demands on the spare fleet because of the extensive vehicle overhaul program in place. On average, NJ Transit holds 125 cars out of service daily, with 34 allocated for preventive maintenance and overhaul programs. Running repairs are low at 33 cars per day, constituting under 5 percent of the total available fleet.

NJ Transit has reduced the overall age of its fleet and increased its reliability. Finally, NJ Transit states that because of its high-speed operation on the Northeast Corridor, more maintenance is required on rail car wheels because of fatigue and high temperature problems. The electric MU cars are semi-permanent married pairs, and as a result, if one car breaks down, the entire married pair is removed from service.

Conclusions

The number of spare vehicles required by NJ Transit's commuter rail operation is influenced by several factors. NJ Transit has to provide quality equipment for premium service. It cannot afford to underestimate its need for spare vehicles and thus, compromise its ability to meet high service standards.

Southeastern Pennsylvania Transportation Authority (SEPTA)

Fleet Characteristics

SEPTA's regional system operates seven lines within the five-county area surrounding Philadelphia, with a fleet of 346 railcars, including 7 locomotives, 304 MU electric cars, and 35 push/pull coaches. The average age of the MU cars is 20 years. Management reports that it uses gap trains, which constitute 3.4 percent of the PVR (265 cars) for the MU fleet. SEPTA officials report a 21 percent spare ratio.

Operating Environment

SEPTA's regional rail system has experienced a significant drop in ridership over the last 5 years. Most recently, the ridership significantly decreased during a major construction project, Railworks. Now, ridership is expected to return to preconstruction levels. Moreover, there are many service restoration and expansion projects planned for the immediate future. It is anticipated that ridership will continue to rise in the coming years and there will be a concomitant decrease in the spare ratio.

Currently, there are excess railcars at this agency. But SEPTA officials report that, as a result of the ridership initiatives and planned service expansions, more cars will be required for peak service, decreasing the spare ratio to a forecasted 17 percent. Thus, it would not make sense to decrease the present fleet size pending this upswing in ridership. There are many capital-funded plans designed to attract riders to mass transit: new stations, more parking at various stations, improved local service, and the institution of express service on other lines. Further, beginning in 1995, the Pennsylvania Department of Transportation is scheduled to reconstruct I-95 from the New Jersey state line to the Delaware state line over a 10-year period. Drivers are being strongly encouraged to turn to mass transit as a remedy to increased congestion.

Maintenance Practices

SEPTA reports that it has a number of maintenance issues as a result of its aging fleet. It reports 20 to 40 cars out of service for running repairs out of a total of 339 cars. Despite relatively frequent inspections, a repair program of 60 days, and a major 5-year overhaul cycle, this agency continues to experience problems with out-of-service vehicles, which may also relate to its aggressive passenger amenities program. The current excess spare vehicles assist the agency in guaranteeing service delivery.

Conclusions

Ridership is likely to increase on SEPTA's Commuter Service with a corresponding increase in peak vehicle requirements and a decrease in the spare ratio. The number of vehicles needed has been calculated at 29 cars. In the interim, it is practical to hold onto to any excess vehicles and to retain the trained maintenance personnel to ensure that when the new riders arrive they will find a safe, reliable, and clean transit fleet waiting for them.

GO Transit (Toronto)

Fleet Characteristics

GO Transit in Toronto, a small commuter rail system, operates seven lines with 306 coaches with an average age of 9 years, and 49 locomotives, with an average age of 4 years. The PVR is 278 coaches, which includes one 10-car consist as a gap train and 36 locomotives. The number of spare vehicles (10 percent) is extremely lean, yet this system continues to make service despite severe weather problems. The agency indicates that its on-time performance is between 95 and 97 percent.

Operational Environment

Like other northeastern Canadian properties, severe weather conditions significantly impact service. But with its welldesigned and effective inspection and heavy maintenance programs, GO Transit continuously provides quality service with a reliable fleet. There are other beneficial operating characteristics. First, the system does not operate with married pairs; all its cars are singles, eliminating concerns about coupling and uncoupling cars. If there is a need to remove a car, the train consist can run with one less car. Second, the maintenance officials also indicate that the coaches are well designed and require limited maintenance activity. Finally, compared to other transit properties, the fleet is relatively young: all but 80 of the cars are less than 12 years old and all the locomotives are less than 6 years old.

GO transit recently leased 25 cars to LACMTA Metrolink, a new commuter rail line in Los Angeles. In doing so, GO Transit decreased its spare fleet significantly. In addition, it permitted Metrolink, a new commuter rail system, to increase its service gradually without resorting to large costly purchases, which would have been required without GO Transit's assistance. When the cars are returned, GO Transit will use them to support its increased vehicle needs due to expanding service.

Maintenance Practices

GO Transit officials report that an excellent inspection and repair program allows them to operate with few spare vehicles. Every 2 weeks an entire train, including the locomotive, is brought into the shop for a preventive maintenance inspection. The train is kept together; it is taken apart only when major repair work requiring more than 1 day to complete is necessary. The gap train is used to replace this train while it is out of service. On one shift, a dedicated team of 9 to 12 maintenance personnel work on the train and repair everything they find. The maintenance facility is set up to handle this kind of inspection with an underdeck long enough to fit the entire train over it, as well as side decks for floor-level entry. By repairing all items in this way, GO Transit has reduced the number of running repairs and in-service breakdowns to one or two per week.

GO Transit also has a major overhaul program that brings in all the coaches every 6 to 8 years to upgrade seats, carpeting, and other cosmetic items, and every 3 years the coach is brought in for inspection and replacement of major subsystems.

Conclusions

GO Transit officials indicated that their current low spare ratio is quite adequate. They also indicated that keeping a large number of vehicles on-site would only be essential if they were to implement an aggressive car rebuild program or use more gap trains in service. Given this agency's intensive maintenance program, which has significantly improved the quality of its fleet, excess vehicles are not required.

CHAPTER FOUR

SIZING THE FLEET

IMPEDIMENTS

"Right sizing" a rail fleet is a major concern and challenge for the transit industry today. There are problems in disposing of excess vehicles with the uncertainties of critical planning in purchasing vehicles for future use, and the long lead time required to procure new vehicles. With rapidly changing service levels, resulting from downward ridership trends and, at newer agencies, the failure to complete planned extensions or to open new routes, it is difficult for an agency to have the right number of vehicles at any given moment. In addition to the long-term challenges, the number of cars required for peak service also fluctuates from year to year, month to month, and day to day.

Survey results show that maintaining a fleet plan with just enough rail cars requires careful long-term planning and the willingness to operate with a lean fleet until appropriate adjustments can be made. However, managing a lean fleet requires an aggressive, well-conceived maintenance plan to ensure that vehicles are properly maintained throughout their useful life. Ineffective or inadequate maintenance practices will undermine the best efforts to operate with as few spares as possible.

There are many factors that influence an agency's ability to "right size" its fleets:

- The cost of disposing of rail cars within their useful life, particularly those that have been rehabilitated with federal dollars,
- The inability to warehouse excess vehicles because of a lack of storage space,
- The limitations of labor agreements that curtail the flexibility to reassign bargaining unit employees when "down sizing,"
- The limited opportunities to buy vehicles in small quantities at reasonable cost,
- The long lead times from design to delivery that lead to purchasing more rail cars than immediately needed,
- The limited ability to lend or borrow vehicles both among and within agencies because of the customization of rail fleets, and
- Fluctuations in service requirements that make it difficult to reconcile vehicle needs over the short term, and as a result of structural changes in ridership, also over the long term.

STRATEGIES

Despite the challenges to correctly sizing a fleet, some strategies identified in this synthesis could assist transit agencies to develop:

- Good patronage estimates--Critical analyses of long-term fleet requirements allow agencies to better plan vehicle needs. Agencies might consider delaying or eliminating the large vehicle purchases that are dependent on speculative events anticipated to occur in the future.
- Options to purchase--Most agencies today negotiate options to purchase additional vehicles on new railcar purchases. Based on analyses of ridership trends and fleet utilization, the agency can carefully consider whether to exercise the option. Because many vehicle purchases extend over a 4- or 5-year period, there is adequate time to reassess needs before exercising the option. For example, CTA is concluding a vehicle purchase and has elected not to exercise an option to purchase an additional 218 vehicles because its ridership projections do not indicate a need for further expansion of service at this time.
- Vehicle standardization--Use of a simple, standardized railcar design increases the ability to buy from and sell to other agencies, to exchange with other agencies, and to shift within a single agency.
- Joint specifications--Cooperative buying between two or more transit systems, particularly new starts requiring smaller volumes of railcars, permits agencies to buy in small quantities while achieving savings with large quantity purchases.
- Warehousing--While warehousing excess vehicles is an unattractive alternative for many officials, it is a viable alternative and an opportunity to improve fleet performance by limiting maintenance resources to active service vehicles.
- Storage--Short-term storage by rotating vehicles out of active service is effective and is a more acceptable alternative than long-term warehousing. Metro-Dade employs this method to handle the excess vehicles on its property.
- Disposal--When new railcars arrive, timely disposal of railcars exceeding their useful life, before the agency becomes accustomed to operating with a large fleet, is essential to good fleet management.
- Fleet size limits--Survey responses show that agencies operate with the fleet they have and develop creative strategies to ensure that they meet service requirements, overcoming any impediments. SEPTA Orange line and METRA are primary examples of how to manage with very lean fleets when no other options exist. At both of these systems strong maintenance programs are in place to ensure vehicle reliability.
- Retirement--Rail cars beyond their useful life should be disposed of as a part of an overall plan to reduce the fleet. Improved procedures for scrapping or retiring vehicles should be used.

DISCUSSION

The survey responses disclosed that systems with low spare ratios have the most reliable fleets and the lowest share of inservice failures. For example, MTA NYC Transit, SEPTA (Orange Line), TTC, and the METRA commuter rail systems operate with very few spare vehicles, yet the reliability of their fleets is very high, as measured by the number of vehicles out of service for running repairs during peak service. Each of these agencies has strong preventive maintenance programs with short inspection cycles.

With the exception of METRA, the maintenance officials of these systems state that they deliberately attempt to operate with few spares so that they can focus their efforts on a minimum number of cars. METRA states that the agency needs every vehicle because its ridership demands are such that it does not have the luxury of excess downtime for any vehicle. As its staff explain, MTA NYC Transit deliberately "runs tight," because increasing its fleet size would be too costly, given its large system and lack of adequate space to accommodate more vehicles in its yards. Thus, MTA NYC Transit has little choice but to ensure that the vehicles it does have for service are highly reliable and available.

There is a fine line between having too many and not enough cars to meet peak service requirements and to ensure good maintenance. Careful attention to this issue is required to ensure that the maintenance staff does not become too preoccupied with daily operating conditions, as this also can compromise the fleet over the long term. For example, PATCO stated that when its fleet was inadequate to meet increased service demands in the 1970s, the agency was unable to begin the overhaul work that is necessary to maximize the vehicles' service life. This had an adverse effect on reliability. After new cars had been acquired to take the pressure off the older fleet, PATCO took the time to rehabilitate the older cars to a high degree of readiness. Careful analysis of equipment and maintenance needs as well as use is critical for optimum performance and a well-managed fleet.

CHAPTER FIVE

CONCLUSIONS

As recorded in the synthesis survey results, many maintenance officials are eager for innovation in fleet planning as they look for ways to cut costs, improve fleet reliability, and decrease fleet size. They do not invite spare ratio regulations nor do they agree about establishing a uniform spare ratio for all rail systems. Professionals in the rail transit field hold the view that rail transit equipment, maintenance practices, and operating environments do not lend themselves to a single, optimal spare ratio target. The following section summarizes critical variables that affect fleet planning and determine a rail transit agency's spare ratio factor.

CRITICAL VARIABLES

The survey of 21 rail transit systems in the United States and Canada demonstrated that not only were there wide variances in the spare ratios reported, but there were divergences among the components of the calculation and the methodologies used to determine the spare ratio. It became apparent early in the analysis that a meaningful comparison among rail systems was impossible without standard definitions and methodologies. Nevertheless, participating agencies provided helpful information and comments regarding spare ratio, which are summarized and listed next.

Critical variables that tend to raise the spare ratio or keep agencies from disposing of excess vehicles:

- Aging fleets with high maintenance downtime,
- Gap trains used in service but not included in the peak vehicle requirement (PVR),
- Difficulties in disposing of surplus cars,
- Cost of retiring cars that have not reached the end of their useful life,
- Concerns that fleet reductions may compromise quality service objectives,
- Concerns that downsizing may impair ability to meet unexpected future demand,
- Hopes that current ridership declines will turn out to be temporary,
- Heavy overhaul and rebuild programs that take vehicles out of service for extended periods,
- Difficulties in providing passenger amenities that take vehicles out of service,
- Large infrequent vehicle purchases coupled with concerns of underestimating future needs, and
- Extensive use of vehicles in married pairs and multiple-unit consists.

Critical variables that tend to reduce the spare ratio:

- Quality maintenance programs that lead to high vehicle availability,
- Ability to temporarily remove excess cars from the total active fleet (TAF) for short periods,
- Capability of moving cars among lines in same system,
- Maintenance labor agreements conducive to quality improvements,
- Quality maintenance employees,
- A "lean" fleet management philosophy,
- Ability to lend/borrow or buy/sell vehicles from other agencies,
- Limited or costly storage space, particularly in city centers,
- Ability to procure "standard" cars that are interchangeable within a system and with other systems,
- Recognition that inactive cars often lead to maintenance problems,
- Ability to combine with other agencies in joint railcar procurement, and
- Effective use of "options to buy" procurement strategies.

CONCLUSIONS OF FTA STUDY

Although based on different data, the conclusions of the FTA National Rail Spare Ratio Study add context to the conclusions of this synthesis.

Overall, the larger heavy rail systems have operated at lower mean spare ratios over a 7-year span. Heavy rail transit systems with a TAF of more than 500 operated at a 7-year mean of 30 percent, systems with a TAF of 200 to 499 ranged from 26 to 33 percent between the 1985 and 1991 report years, and the smaller heavy rail transit systems operated at a 7-year mean of 70.3 percent. It is important to understand that heavy rail systems are very individualized in the problems they encounter. Many trains are tailored for the specific agencies making the acquisition. Additionally, heavy rail transit agencies often do not operate the same type of heavy rail vehicle throughout all lines providing service. For example, in visiting a few of the rail systems nationally, it is not uncommon to have one agency with several types of heavy rail trains that will operate on only one line within that system. Thus, if unscheduled maintenance occurs, that agency could encounter many delays in service, as well as be burdened with excess spares. Therefore, while a 30 or 40 percent spare ratio may appear high for certain agencies, it is actually a reasonable number when the complexities of the various heavy rail systems are considered.

This FTA study concludes that commuter rail systems nationally have achieved lower spare ratios than other forms of rail transit and, as is true for the heavy rail systems, the largest agencies have the lowest spare ratios. Average spare ratios of the larger commuter rail transit systems, with a TAF of more than 350, have remained fairly constant--under 19 percent between 1985 and 1991. The commuter rail transit systems operating a 100 to 350 TAF average spare ratio fluctuated yearly, with the exception of a decrease from 20.5 percent in 1989 to 11.6 percent in the 1991 report year. The very small commuter rail transit systems operating a TAF under 99 have operated at a 7-year mean spare ratio of 57.1 percent. It is important to note that most commuter rail transit systems do not require the level of maintenance that heavy rail systems do on a regular basis. Additionally, most commuter rail transit systems operate only one locomotive, which pulls the additional vehicles. Many commuter rail agencies' vehicles are not tailored to fit only one system. Thus, the acquisition of railcars by other similar agencies is an option if ridership decreases.

Overall, the rail systems in the United States and Canada have either begun to lower their spare ratio levels or have fluctuated at very low spare ratios annually. Currently, 85 percent of the commuter rail systems nationally are operating at a spare ratio less than 25 percent and 58 percent of the heavy rail systems nationally operated at 30 percent or less spare ratio.

The National Spare Ratio Study concludes that it would be difficult to assess one spare ratio threshold for heavy rail and commuter rail transit systems. Additionally, it is important to note that a national move toward producing heavy railcars that are usable on more than one system is vital. This guidance could begin with new systems nationally, and continue with agencies requesting additional acquisitions or extending existing service.

DISCUSSION

This synthesis has underscored the need for more attention to the role of spare ratios in transit fleet management. There are many factors that must be analyzed in the context of the rail operating environment, some of which are discussed below. They are presented as initial discussion points for the national dialogue that is needed to further the search for a consensus among rail transit personnel throughout the industry.

Married Cars

The fact that many rail agencies use married car consists is important in discussing the need for spare vehicles, as this factor has a major impact on car availability. The spare ratios of systems that use these frequently inseparable consists must recognize that a failure of one vehicle often means failure of the total consist, especially during peak service. Transit systems such as BART, which operate cars with special lead, center, or trail functions, find that they have an added level of complication.

Compatibility

Systems such as SEPTA, MBTA, and MTA NYC Transit have separate fleets that are individualized by lines, each requiring its own spares. Rail systems with such nontransferable cars within their fleets need more cars than systems with fully integrated fleets.

Gap Trains

To avoid service disruption, most systems keep train consists along their routes or in the yards for instant replacement. The use of these gap trains has become an essential component of regular rail transit service for WMATA, PATH, CTA, and MTA NYC Transit. Although the cars are not used every day, it is appropriate to include them within the definition of peak vehicle requirements. They are used frequently and their availability is the key factor in their agency's ability to meet daily service needs.

Defining Long-Term Needs

Many agencies are reluctant to dispose of excess vehicles because they anticipate increased ridership for a number of reasons, including:

- Economic growth and/or population shifts to the service area,
- Reverse commuting,
- Clean Air Act requirements for transit use such as the Employee Trip Reduction Program, and
- Customer service incentives.

More work is required to "right size" fleets in the context of these uncertain and fluctuating ridership trends. Two systems, Metro-Dade and MARTA, deserve special attention because their high spare ratios are caused primarily by an overestimation of ridership at the time the vehicles were initially purchased for the system, notwithstanding cost savings realized in bulk vehicle purchases and the challenge of long lead time currently required to procure new vehicles.

Customization

Rail transit agencies have a hard time disposing of excess vehicles. Railcars are frequently customized for individual systems to fit tunnels, overpasses, and special operating conditions, such as track gauges, grades, curves, and stations. For example, CTA has shorter cars to accommodate sharp turns on its elevated system. Other agencies with different but equally specific requirements might not want to purchase these kinds of cars. Most railcars are not readily saleable or transferable.

Aging Fleets

While operating an old fleet is not a guarantee that more spare vehicles well be required, many systems have experienced significant problems because of aging fleets. They require more maintenance attention, particularly if the cars were not well-designed initially, and can be difficult to obtain parts for. The experience of MBTA and SEPTA's Blue Line provide some insight into the problems of aging fleets and the resulting impact on the number of spare vehicles required.

Labor Agreement Issues

Many labor agreements include the conditions under which an agency may decrease the maintenance work force when work is not available. Thus, a transit agency may not be able to realize all potential savings associated with downsizing its fleet.

Good Maintenance Practices

Good maintenance practices, especially a strong preventive maintenance program, will always lengthen vehicle life, and increase daily fleet reliability. When vehicles have received regular, high-quality maintenance over the long term, the fleet builds up a history and experience of good performance. Frequent inspections are especially effective.

TTC and MTA NYC Transit have effective maintenance programs that are based on component life cycles. Although some mid-life overhaul programs may not affect day-to-day reliability, these programs are working in New York and Toronto. Perhaps it is because these vehicles had been overhauled in the past. The effectiveness of these component overhaul programs should be closely examined within the rail maintenance community. Optimum time and/or mileage inspection cycles should be determined to yield the greatest benefits for the industry and the most effective preventive maintenance practices should be identified to increase the life of the vehicle, its daily reliability and availability, thus controlling fleet size and minimizing spare ratios.

Conclusion

The transit industry today is faced with the task of trying to achieve a realistic and efficient spare ratio within the context of operational requirements, existing rail fleets and routes, anticipated near-term needs, the requirements of standard maintenance programs, and the difficulty in quickly acquiring additional cars or quickly disposing of excess vehicles. The survey findings show that spare ratios and related operational and service factors require careful thought before any industry consensus can be reached on definitions, methodologies, and spare ratio levels.

The challenge is to manage fleet size to reduce life-cycle cost without diminishing service standards. This synthesis is only a first step in addressing the complex issues raised by the use of spare ratios in fleet management. There is a need to call attention to many of the concerns raised by respondents. From the many discussions with survey respondents, it is apparent that transit professionals are eager for more information on how to manage better and more cost effectively. Thus, this document will be useful if it sheds some early light on the subject of railcar spare ratios and begins a discussion within and among transit agencies and a dialogue between operating and funding agencies.

GLOSSARY

Average Fleet Age--The cumulative years active revenue vehicles are in service divided by the sum of all active revenue vehicles.

Commuter Rail--Short-haul rail passenger service operating in metropolitan and suburban areas, whether within or across the geographical boundaries of a state, usually characterized by reduced fare, multiple ride and commutation tickets and by morning and evening peak-period operations. This term does not include Light or Rapid Rail (Heavy Rail) transportation.

Consist--Number of cars connected to make up a single Light, Heavy, or Commuter Rail unit. For example, a three-car consist could be three inseparable (married) cars, or three easily separable cars.

Coupled Pair--Two single unit single-end cars (cab at the "B" end) that are coupled at the "R" end to provide a doubleend pair.

Gap Trains (Contingency, Standby, Relay, or Reserve Trains)--Train set(s) stored along the transit route in terminal pockets or in the yards for in-service emergency replacement for trains removed from service for breakdowns. These trains may or may not be staffed for immediate service. Some systems include the Gap Trains in their definition of Peak Vehicle Requirements, particularly when they are needed frequently.

Heavy Rail--Transit service using rail cars with motive capability, driven by electric power usually drawn from a third rail, configured for passenger traffic and usually operated on exclusive rights-of-way. Uses generally longer trains and consists of longer station spacing than Light Rail. Formerly Rail Rapid Transit.

Integration--Capability of transit vehicles from one route or line to be used with other trains or operated on other routes or lines; capability of individual cars in a train to connect or operate at different positions on the train.

Light Rail--A fixed-guideway mode of urban transportation using predominantly reserved but not necessarily grade-separated rights-of-way. It uses primarily electrically propelled rail vehicles, operated singly or in trains. A raised platform is not necessarily required for passenger access. (In generic usage, light rail refers to very modern and more sophisticated developments of these older forms of public transportation.)

Linked Passenger Trips--A linked trip is a trip from origin to destination on the transit system. Even if a passenger must make several transfers during a journey, the trip is counted as one linked trip on the system. A passenger who rides three vehicles to work, for example, takes one linked trip on the system, but three Unlinked Passenger Trips because the passenger rode on three different vehicles.

Locomotive--A self-propelled vehicle, usually electric or diesel, that pulls or pushes rail cars along railroad tracks.

Long-term Hold--A revenue vehicle which is held out of service over a substantial period (usually more than three days), for extensive maintenance or repair. This does not include vehicles awaiting disposal--it is anticipated that the vehicle will eventually be put into revenue service.

Make Service--Industry language or "term-of-art" meaning to provide sufficient vehicles to meet peak vehicle requirements.

Married-pair Cars--Married-pair cars are semi-permanently or permanently coupled cars, which may share some systems and sub-systems. Each married pair has all of the equipment required for independent married pair operation with an engineer's operating station at the B-end of each vehicle.

1. Uncouple a married pair from a train to reduce the length of the train from, say, 8 cars to 6 or 4 cars.
2. Disconnect one car of a married pair from its mate (in a shop).

Mean Distance Between Failures--The average mileage that a transit vehicle or train travels between mechanical failures (defined in FTA Section 15, Form 402) that remove it from service.

MU Car (Push/pull Car)--A self-propelled vehicle, electric or diesel, which can move independently either alone or jointed with other similar vehicles on railroad tracks.

Overhaul--Extensive restoration of revenue vehicles including replacement of mechanical components and refurbishment of vehicle's interior and exterior as necessary. Usually occurs near the scheduled mid-life of the vehicle.

Peak Vehicle Requirement (PVR) (Vehicles Operated in Maximum Service)--The number of revenue vehicles operated to meet the annual maximum service requirement. This is the revenue vehicle count during the peak season of the year, on the week and day that maximum service is provided. It excludes atypical days and one-time special events.

Rehabilitation--Rebuilding of revenue vehicles to original specifications of the manufacturer. This may include some new components but has less emphasis on structural restoration than would be the case in a remanufacturing operation, focusing instead on mechanical systems and vehicle interiors.

Remanufacture--Structural restoration of revenue vehicles in addition to installation of new or rebuilt major components to extend service life.

Replacement--Replacement of revenue vehicles that have reached the end of a minimum normal service life.

Running Repairs--Mechanical and other types of ordinary repairs to revenue vehicles that can be accomplished in the shop to which the rail car is assigned.

Single Cars--Vehicles that have all equipment necessary for independent operation with an engineer's operating station at each end of the vehicle.

Spare Ratio--The number of spare vehicles divided by the vehicles required for annual maximum service. Usually expressed as a percentage, e.g., 100 vehicles required and 20 spare vehicles is a 20 percent ratio.

Spare Vehicles--Revenue vehicles available to the transit agency to accommodate routine and heavy maintenance requirements as well as unexpected vehicle breakdowns or accidents while preserving scheduled service operations.

Total Active Fleet (TAF)--All revenue vehicles held at the end of the fiscal year, including those in storage, emergency contingency, awaiting sale, etc.

Total Available Fleet--All revenue vehicles available for service, generally excludes long-term holds and sometimes vehicles held out of service for scheduled service.

Unlinked Passenger Trips--The number of passengers who board public transportation revenue vehicles. A passenger is counted each time he/she boards a vehicle even though he/she may be on the same journey from origin to destination.

APPENDIX A

Questionnaire

+ October 31, 1993

QUESTIONNAIRE
TRANSIT COOPERATIVE RESEARCH PROGRAM, TOPIC-3A-2
SYSTEM-SPECIFIC SPARE RATIO-RAIL

Organization:______________________________

Address:______________________________

____

Individual Filling out Questionnaire:

Name:______________________________

Title:______________________________

Department:______________________________

Telephone:______________________________

1. What kind of rail transit service do you provide?*

Commuter rail:

Rapid Transit:
Subway:
Elevated:
Light Rail:

(Do not include buses. Use separate questionnaire for each type of service, if your system provides both rapid and commuter rail services.)

2. What is the total number of employees working in your Agency?

____

3. Please describe your rail operations as indicated below:

	REVENUE MILES	REVENUE HOURS
Commuter Rail:	________	________
Rapid Transit:	________	________
Subway:	________	________
Elevated:	________	________
Light Rail:	________	________
Total for system:	________	________

4. What is the annual number of unlinked passenger trips for your rail system?

Commuter rail:______________________________
Rapid Transit:______________________________
Subway:______________________________
Elevated:______________________________
Light Rail:______________________________

5. How many rail lines do you operate? Indicate each line and length of line.

Line	Length of Line	# of Station
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______

6. How many vehicles do you have in your total active fleet(TAF)? Total Active Fleet is defined as all revenue vehicles held at the end of the fiscal year, including those held out of service for long term maintenance, vehicle overhauls, emergency contingency, spares or otherwise held out of service. Do not include vehicles that are scrapped or are awaiting sale.

____

7. Has your fleet size remained the same for the last five years?

Yes:
No:

APPENDIX A (Continued)

If no, indicate the following:

Have you replaced any cars?:_______________________
Year of new car acquisition:______________________
Number of cars acquired:___________________________
Number of cars retired:___________________________
Year of retirement:_______________________________

8. Please fill in the following information describing your fleet.

Vehicle Model*	**Number**	**Age**	**Consist***
____________	______	___	__________
____________	______	___	__________
____________	______	___	__________
____________	______	___	__________
____________	______	___	__________
____________	______	___	__________
____________	______	___	__________

(* indicate whether this class of car can be integrated with others.
** indicate whether single or married cars)

9. a) What is the average train length by line during your peak service?____

b) What is the average train length for the system during your peak service?
____

10. What is your peak operating time?

Morning:
Afternoon:
Weekday:
Weekend:

11. What are your peak service requirements?

Year	**Total Vehicles**	**Number of Vehicles Required for Peak Scheduled Service**
1993	___________	___________________________
1992	___________	___________________________
1991	___________	___________________________
1990	___________	___________________________
1989	___________	___________________________

12. How do you calculate your peak service requirements? Please explain.
____
____
____
____

13. Do you include extra trains in your peak vehicle requirement? Extra trains are defined as trains which are set aside to support service but exceed the actual number of trains required for scheduled service, and are sometimes referred to as relay or gap trains.

Yes:
No:

14. If you answered yes to question 13, indicate what percentage of your peak vehicle requirement are extra trains as defined in question 13?__________________________

15. If you answered no to question 13, do you set aside extra trains, as defined above, that you do not actually need for service?

Yes:
No:

16. How many times per week do you use the extra trams to cover out of service trains?____

17. Where do you store your extra trains?

In the yard?________________
Along the route?____________
Other?______________________

18. What is your current spare ratio?________________________

19. How did you arrive at that number? Explain methodology used.
____
____
____
____
____
____
____

20. State the average number of cars held out of service during peak service for the following

APPENDIX A (Continued)

reasons: (If the car is part of a consist, count as two cars held out of service.)

Inspections______________________
Heavy Maintenance________________
Vendor/Contract work_______________
Running Repairs_____________________
Parts not Available__________________
Vehicle Overhaul____________________
Other_____________________________

21. How frequently must you perform inspections?

Type of Inspection	Time	Mileage
_______________	_____	_________
_______________	_____	_________
_______________	_____	_________
_______________	_____	_________
_______________	_____	_________

22. What time of day and on what days of the week are inspections done?_____
____
____

23. Do you have a vehicle overhaul program?

Yes
No

24. If yes, what is the overhaul cycle for your rail vehicles by subset?

Type of Vehicle	Overhaul Cycle
_____________	_____________
______________	_____________
______________	_____________
______________	_____________
______________	_____________

25. What is the average number of daily repairs for the fleet?

1993_________________
1992_________________
1991_________________
1990_________________
1989_________________

26. What has been your average yearly mean distance between failure?

1993____________________
1992____________________
1991____________________
1990____________________
1989____________________

27. In calculating your mean distance between failure, what constitutes a failure?______________________________

(Please attach a copy of your specifications.)

28. When you substitute trains for in service failures, does that count as a failure in calculating your mean distance between failure?_____________________________

29. If you run married pairs, does a breakdown of one car count as one failure or two?

30. Is it the policy of your agency to hold trains out of service for non-safety related passenger amenities, such as cleanliness, torn seats, air conditioning/heat etc.? If yes, please indicate those items for which you will hold trains out of service.
____

31. In what way does this policy affect the number of spare cars/trains that you have available?____

32. What is your operating costs per mile?___________________

33. Please indicate you annual VEHICLE MAINTENANCE EXPENSE (VME).
Vehicle maintenance expenses are defined as total operating expenses associated with the inspection, maintenance, and repair of vehicles, such as mechanic wages and fringe benefits, maintenance supplies, repair parts, outside and/or contract maintenance, and repair work.. On the labor side, include the salaries and fringe benefits of all employess except management, stoclroom personel, and administrative and support personnel.
____
____
____
____

34. What is the ratio of mechanics to vehicles?_____________

35. What is the ratio of vehicles to mechanics?____________

APPENDIX A (Continued)

36. How many car shops do you have and where are they located in relationship to the lines?

Car Shop	**Location**
_____________	_____________
_____________	_____________
_____________	_____________
_____________	_____________

37. Do you have to dead head. back to the car shops when trains leave service?_________

38. If yes, how many lines do you deadhead back to the car shop?
____

39. Do you believe that a 20% spare ratio is feasible for your system?

Yes
No

40. If no, please explain why not.________________________________
____
____
____
____

41. Do you believe there should be a standard spare ratio for rail transit vehicles?

Yes
No

42. Please explain your reasons for either a yes or no answer.______________
____
____
____
____

43. Are there specific problems with your car fleet that would cause it to deviate from a standard spare ratio?____
____
____
____
____

APPENDIX B

UMTA Circular C 9030.1A

UMTA C 9030.1A
9-18-87

(2) Rail Requirements

(a) Replacement. Any rail vehicle proposed for replacement must be at least 25 years old. While 25 years is the minimum replacement life for Federal capital funding purposes, grantees may continue to specify longer service life requirements in their procurement documents. For purposes of Section 9 rail vehicle replacement projects, the age of the vehicle to be replaced is its age at the time the proposed new vehicles are introduced into service.

(b) Rebuilding. Rebuilding must be more cost effective than the purchase of equivalent new rolling stock. Thus, the cost of rebuilding should normally not exceed the yearly amortized value (straight line method) of a new vehicle multiplied by the number of years of useful life to be added to the vehicle through rebuilding. The service life of the vehicle must be extended by at least 40 percent of the original service life. Rolling stock to be rebuilt must have reached the end of its minimum normal service life. Routine maintenance and repair costs are not eligible capital expenses.

(c) Spare Ratio. Because rail transit operations tend to be highly individualized, no specific guideline is being suggested for a spare ratio for rail transit operations. Nevertheless, rail transit operators should be aware that their spare ratios will be examined during the TIP/AE and triennial review.

(d) Rail Rolling Stock Overhaul. Overhaul of rail rolling stock is considered to be the one-time rebuild or replacement of major subsystems on revenue producing rail cars and locomotives commonly referred to as midlife overhaul. To be eligible for UMTA assistance, the rolling stock to be overhauled must have an accumulated service life of at least 12 years.

THE TRANSPORTATION RESEARCH BOARD is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering It evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 270 committees, task forces, and panels composed of more than 3,300 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, the Association of American Railroads, the National Highway Traffic Safety Administration, and other organizations and individuals interested in the development of transportation.

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. Upon 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 Bruce Alberts 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. Robert M.White is president of the National Academy of Engineering.

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