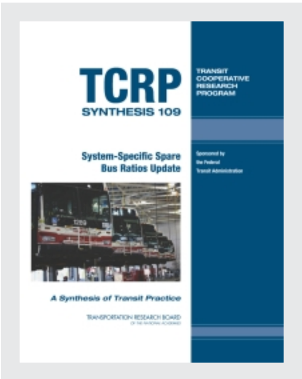

System-Specific Spare Bus Ratios Update

DETAILS

60 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-27119-6 | DOI 10.17226/22409

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP SYNTHESIS 109

System-Specific Spare Bus Ratios Update

A Synthesis of Transit Practice

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Subscriber Categories
Public Transportation • Operations and Traffic Management • Vehicles and Equipment

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

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2013
www.TRB.org

TRANSIT COOPERATIVE RESEARCH PROGRAM

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

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

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

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

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

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

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

TCRP SYNTHESIS 109

Project J-7, Topic SA-32
ISSN 1073-4880
ISBN 978-0-309-27119-6
Library of Congress Control Number 2013955097

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TRANSIT COOPERATIVE RESEARCH PROGRAM

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Business Office
500 Fifth Street, NW
Washington, DC 20001

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Printed in the United States of America

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Cover figure: Buses on lifts. *Credit*: Danielle Scott.

FOREWORD

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

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

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

PREFACE

By Donna L. Vlasak
Senior Program Officer
Transportation Research Board

This report documents successful practices in the United States and Canada, and presents information on efforts employed to achieve optimal bus fleet size and effective spare bus ratios. The objective is to update the findings of *TCRP Synthesis 11: System-Specific Spare Bus Ratios*, as significant changes have occurred in the transit industry since 1995. This synthesis provides valuable guidance to transit agencies on how various factors may affect optimal fleet size. The intended audience for this synthesis can be bus transit management, operations, and all supporting staffs and stakeholders.

A literature review, a survey of selected transit agencies with an 80% response rate, and four case examples report on agency bus fleets with numerous unique attributes, service demands, environmental factors, and maintenance issues.

Martin Minkoff and Lindsay Martin, ICF International, Seattle, Washington, collected and synthesized the information and wrote the report, under the guidance of a panel of experts in the subject area. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SYSTEM-SPECIFIC SPARE BUS RATIO UPDATE

SUMMARY

Since 1995, when *TCRP Synthesis 11: System-Specific Spare Bus Ratios* was published, significant changes have occurred in the transit industry. The purpose of this synthesis is to update the findings of *TCRP Synthesis 11*, providing guidance to transit agencies on how various factors may affect optimal fleet size. It describes efforts agencies have employed to achieve the optimal fleet size and effective spare ratios and document successful practices in the United States and Canada.

To develop this synthesis, the authors conducted an extensive TRIS literature search and document review, supported by readily available Internet search engines; a survey of selected transit agencies; and follow-up interviews with four case example agencies to gather information on the state of practice related to spare bus fleet ratios and optimal bus fleet sizing, including challenges, lessons learned, and gaps in information.

FTA's policy on bus spare ratios is found in FTA Circular 9030.1C, *Urbanized Area Formula Program: Grant Application Instructions*, chapter V, paragraph 9.a.5. It states that the "number of spare buses in the active fleet for grantees operating 50 or more revenue vehicles should not exceed 20 percent of the number of vehicles operated in maximum service." FTA's policy also states that "the basis for determining a reasonable spare bus ratio takes local circumstances into account," a further indication of some flexibility with regard to the maximum number of spare buses allowed by FTA. Owing to the possibility that extra buses may exist on property temporarily as new buses enter the fleet piecemeal and older buses are not yet retired, the Circular also states that "spare ratios will be taken into account in the review of projects proposed to replace, rebuild, or add vehicles." The synthesis found that FTA does grant some degree of latitude and considers local conditions when evaluating bus spares, particularly in their consideration of action plans required of grantees that have exceeded the 20% threshold. In such plans, grantees provide FTA with the approach they intend to take over a period of time to bring their spare ratio back to an acceptable level.

In 2010, APTA, on behalf of its member transit agencies, approached the FTA requesting consideration of changes to the FTA's recommended spare bus ratio guidelines. This initiated an on-going dialogue between APTA and the FTA, and though no changes to FTA guidelines have been made so far, this exchange reflects the critical importance of the spare ratio issue to both the transit industry and the federal government. Nevertheless, the TRIS search underscored how little research the topic has generated over the last 25 years—a period that has experienced rapid change in the operation and maintenance of transit bus fleets and the vehicles themselves—producing only eight documents published between 1988 and 2012.

In general, the literature recognizes the desirability of limiting the number of spare buses in a fleet to the "proper" number that adequately balances and supports both the agency's peak transit service needs and its bus maintenance requirements. The literature also recognizes the high cost of carrying more spare buses in the fleet than necessary, and points out that a larger than necessary spare ratio may be symptomatic of other issues, including fleet and service characteristics, insufficient maintenance training and staffing, and external operating and service factors.

A survey questionnaire was developed for this synthesis focusing on the various attributes that drive spare bus needs and fleet spare ratios. It also gathered information on actions that agencies have implemented in their attempts to reduce fleet spare ratios, and their results.

A core sample of 48 U.S. and Canadian agencies representing a broad cross section of transit systems operating buses was developed, and the goal of 38 completed surveys (a 79% response rate) was achieved. The core sample was based on (1) geographic/climatic distribution; (2) bus fleet size; (3) past participation in the 1995's *TCRP Synthesis 11*: *System-Specific Spare Bus Ratios;* and (4) known prior interest in the topic.

After analyzing the surveys, consulting with the topic panel, and assessing the results of the literature review, the authors interviewed representatives from four case example agencies for more in-depth information and insights. Interviews were conducted by telephone with representatives of:

- Chicago Transit Authority
- Denver Regional Transit District
- Santa Clara Valley Transportation Authority
- City of Winnipeg (Manitoba) Transit Department.

Challenges in managing bus fleets and spare ratios were identified in both the survey and case examples—many, though not all, rooted in an agency's financial constraints. Those who identified such challenges listed reduced capital dollars for needed bus replacement; reduced maintenance staffing; and transit service reductions (resulting in unused vehicles) as major impacts. Among suggestions for addressing such challenges were sustainable funding for the timely replacement, rehabilitation, and overhaul of aging, high-mileage buses; improved vehicle performance and reliability; increased staffing and training resources; and facility upgrades.

CHAPTER ONE

INTRODUCTION

Since 1995, when *TCRP Synthesis 11: System-Specific Spare Bus Ratios* was published, significant changes have occurred in the transit industry. Not only have almost all transit agencies replaced their fleets, but new bus configurations and alternative propulsion systems have been widely deployed. At the same time, transit vehicles have become more challenging to maintain and operate, owing to the introduction of such features as electronic fare boxes, global positioning tracking systems (GPS), automated stop announcements, and on-board surveillance systems. Anecdotal information suggests that the increased complexity of transit vehicles and the environmental challenges under which they operate may have resulted in an increased need for spare vehicles, with a corresponding increase in spare bus vehicle ratios.

PROJECT OBJECTIVES

The purpose of this synthesis is to update the findings of *TCRP Synthesis 11* on how various factors affect optimal fleet size. It includes, but is not limited to, the following:

- Definitions of spare ratio and transit agency accommodations of specific local service factors;
- An update of key variables affecting spare ratios today and changes over time;
- Documentation of agencies' maintenance approaches, programs, out-of-service criteria, practices, and challenges related to maintaining spare ratios;
- The influence of service and operating environments on spare ratios; and
- Innovative approaches to managing spare ratios.

TECHNICAL APPROACH

An extensive literature search and document review was conducted on the current state of the practice related to spare bus fleet ratios and optimal bus fleet sizing. Documents were obtained both through the web (by means of TRIS and other Internet search engines) and, for out-of-print publications, from the TRB archives.

The survey of selected transit agencies was designed specifically for this synthesis; and representatives from four case example agencies were interviewed for more in-depth information and insights.

ORGANIZATION OF THIS REPORT

Following this introductory chapter, chapter two summarizes the findings of the literature review. Chapter three discusses the survey methodology and results, and chapter four contains summaries of the four case examples. Chapter five reports the synthesis conclusions, including challenges and promising practices, and suggestions for further research; and is followed by references and a bibliography of additional resources.

Appendix A contains a copy of the on-line questionnaire; Appendix B provides a list of all transit agencies that participated in the survey; and Appendix C contains a proposed research problem statement for consideration by the TCRP as a project to further develop applicable resources for transit agency practitioners. Appendix D, available web-only, includes a compilation of individual agency survey responses. Appendix D can be accessed through the following URL: www.trb.org, search on TCRP Synthesis 109.

CHAPTER TWO

LITERATURE REVIEW

The literature review related to bus fleet spare ratios generated only eight documents published between 1988 and 2012, which will be discussed in reverse chronological order.

LITERATURE REVIEWED

Li, T., A. Gan, and F. Cevallos, "Characteristics of Bus Transit Vehicles in the United States: How They Have Changed Over a Quarter Century," presented at the 53rd Annual Transportation Research Forum, Tampa, Fla., Mar. 15–17, 2012.

Using data drawn from the National Transit Database (NTD), this research paper looked at the national trends of major characteristics associated with bus revenue vehicles. The characteristics examined included the number of vehicles transit fleets, the spare ratios, average age of the fleet, average capacity, Americans with Disability Act (ADA) accessibility, vehicle reliability, and vehicle operations and maintenance costs.

According to this research, spare ratios have consistently exceeded the maximum of 20%, as suggested by the FTA; buses operated by contractors tended to be significantly newer than those directly operated by transit agencies (although the gap has narrowed); vehicles operated directly by transit agencies tended to have greater seating and standing capacities than those operated by contractors; and by 2006, nearly all bus vehicles were ADA-compliant (and increasingly, vehicles with lifts were converted to vehicles with ramps/low-floors). Among the most significant findings were that the reliability of buses, in terms of the number of mechanical failures per million revenue vehicle-miles, had significantly improved over the years; and that contractors spent less on average than transit agencies in operating and maintaining their vehicles.

Schiavone, J. and X. Wang, *Method and Processes for Transit Training Metrics and Return on Investment*, Transportation Learning Center, Silver Spring, Md., 2011.

This white paper highlighted the critical importance of robust maintenance training programs in the transit industry and quantifying the benefits. The report described an approach to quantitatively evaluating the benefits and value of training programs, explaining that most transit agencies lacked the ability to measure training effectiveness or to use those results to advocate for additional expanded training.

The paper includes an overview of training/learning methodologies; return on investment (ROI) benchmarking and performance monitoring; and guidance for measuring training program performance, including a framework for assessing the "bottom line" business impact of effective training programs.

Some of the key performance metrics identified that could be linked to effective training programs included mean distance between failures, repeat failures, schedule adherence, maintenance cost per mile, and the bus spare ratio. The paper established a strong link between improved maintenance training and the number of spare buses needed to support the transit revenue fleet, pointing out that "one indication of poor maintenance resulting from untrained workers is the need to have a larger ratio of spare buses. The extra buses are needed to account for vehicles that are less reliable and therefore more frequently in the depot, and for untrained workers who typically require more time to diagnose and repair faults."

The paper then offered a methodology with which to estimate the ROI, taking into account training program costs and the cumulative financial benefits received—including, but not limited to, savings from a lower bus spare ratio. As an example, the five-level methodology was applied to Pennsylvania's Keystone Transit Partnership experiment at the Southeast Pennsylvania Transportation Authority (SEPTA) where the ROI was convincingly demonstrated.

Minkoff, M., *Bus Fleet Management in an Era of Increasing Technical Complexity: Analysis of Bus Fleet Spare Ratios, TCRP Project J-06, Task 73*, Transportation Research Board, Washington, D.C., 2009.

This research focused on the significant changes that had taken place over the years affecting bus fleet characteristics and management. The paper examined how the spare bus ratio, as defined by FTA (and previously, the Urban Mass Transportation Administration) is applied in the field. The research focused on answering critical questions related to the impact of several factors on transit agencies' abilities to operate within the 20% fleet-wide spare ratio standard established by the FTA. These factors were increased fleet mix diversity; the introduction of alternative fuels and energy technologies; the implementation of advanced on-board technologies; the profile of transit service types offered to the public (and the interoperability of buses between service types); workforce constraints; and whether a 20% fleet-wide spare ratio was an appropriate benchmark. The research included an analysis of National Transit Database information, an on-line survey, three case examples, and outreach to the FTA. The work offered a set of recommendations and conclusions for consideration under the APTA standards program, including items to consider in developing a recommended practice for calculating bus fleet spare ratios. These included the exclusion of certain vehicle types from the calculation of the fleet-wide spare ratio, and recognized variations in spare bus flexibility needed for different bus fleet sizes: those with fewer than 50 vehicles, those with 50 to 250 vehicles, and those with more than 250 vehicles.

Pierce J. and E. Moser, *TCRP Synthesis 11: System-Specific Spare Bus Ratios*, Transportation Research Board, National Research Council, Washington, D.C., 1995.

This TCRP synthesis documented the critical site-specific variables affecting the number of spare vehicles that bus systems need to maintain and support peak service requirements. The project involved transit managers at a cross-section of agencies of various size and geographic location who responded to a detailed questionnaire and follow-up interviews. This synthesis concluded that although respondents generally acknowledged that right-sizing the fleet improves operations and lowers cost, many reported difficulties in achieving and consistently maintaining the FTA-prescribed 20% spare ratio. The consensus was that more flexibility was required in determining the actual number of vehicles needed to accommodate the different operating environments and service requirements unique to each transit system. Respondents to the survey urged that more emphasis be placed on developing improved bus maintenance techniques that would assist them in minimizing down time and improving vehicle availability, ultimately leading to reduced spare vehicles and lower labor and materials costs. This synthesis found that many agencies have been successful in limiting their spare vehicle fleets as a result of a corporate philosophy of maintaining a "lean fleet"; strong preventive maintenance (PM) programs; regular procurement of new vehicles; effective use of advanced technology for critical maintenance programs; and managing the workforce to create a more cooperative environment.

Branch, P., *National Bus Spare Ratio Study*, Federal Transit Administration, Washington, D.C., 1993.

This FTA study examined national bus spare ratios across all fleet sizes, except those FTA grantees operating fewer than 50 vehicles. This work statistically analyzed spare ratio percentages as a whole and by fleet size groupings over a five-year period between 1985 and 1990. In summary, the study found that two-thirds of all transit agencies sampled achieved a spare ratio of 25% or less, and 79% achieved a 30% spare ratio or less. This FTA work concluded that the transit industry as a whole has worked toward achieving the FTA's goal of a 20% fleet-wide spare ratio.

Jaraiedi, M. and W. Iskander, "Statistical Evaluation of Spare Ratio in Transit Rolling Stock," *Transportation Research Record 1221*, Transportation Research Board, National Research Council, Washington, D.C., 1989, pp. 88–90.

In this research work, statistical techniques were used to analyze the relationships between variations in spare ratio and characteristics of bus transit properties. Section 15 (the precursor to the NTD) data for 1984 were used for this analysis. The study analyzed 14 important variables that affected bus spare ratios; and classified transit agency fleets into groups with high, average, or low spare ratios. The study found that there is a significantly lower average total number of road calls per vehicle hour for properties that have a low spare ratio than there is for those that have medium or high ratios. Mechanical and total road calls per vehicle-mile exhibit similar patterns. The study concluded that the percentage of federal assistance to total revenue has a lower average in systems with lower spare ratios. The authors further concluded that properties with high spare ratios rely on federal assistance more than have those that have low spare ratios.

Iskander, W., M. Jaraiedi, and S. Niaki, "Simulation Study to Evaluate Spare Ratios in Bus Transit Systems," *Transportation Research Record 1221*, Transportation Research Board, National Research Council, Washington, D.C., 1989, pp. 77–87.

This work involved the development of a simulation model that could be used to assess the appropriate spare ratio level needed to maintain a desirable level of service dependability. The model evaluated the effects of the rates of bus mechanical failures, repair time, and other characteristics on the spare ratio and overall performance of the transit system. The model was validated and used to simulate the bus operations of an existing transit system.

Iskander, W. and M. Jaraiedi, *Evaluation of the Spare Ratio Concept in the Management of Transit Rolling Stock*, Urban Mass Transportation Administration, Washington, D.C., 1988.

This work was the basis of the last two publications described, investigating the issue of spare vehicles and spare ratios in transit bus fleets. Statistical techniques were used to investigate the relationship between variations in the spare ratio and characteristics of bus transit systems. A simulation model was also developed in order to analyze the effect of different variables and characteristics on the choice of a proper value for a fleet's spare ratio. Procedures were developed to determine optimal strategies for bus acquisition and retirement, and of allocation of funds to purchase new equipment in order to maintain a desirable level of service dependability. The model was validated and used to study bus operations of the Kanawha Valley Regional Transportation Authority in Charleston, West Virginia.

SUMMARY

This literature review underscored the limited research that has been performed on this topic over the last 25 years, despite the extensive evolution of transit bus agencies' operation and maintenance policies.

Li et al. (2012) provided an excellent context for reviewing and understanding spare bus-related issues with their analysis of the significant changes in transit fleet characteristics over the last 25 years. Schiavone and Wang (2011) provided insights and methodologies for improving the state of maintenance training at transit agencies, making a case for increased expenditures on maintenance training as a positive ROI.

Pierce and Moser (1995) and Minkoff (2009) explored the wide variation among transit agency bus fleets, operating environments, service characteristics, and maintenance program; and the need for flexibility in determining the appropriate number of spare buses required.

Branch (1993) provided a thorough statistical analysis, documenting bus fleet spare ratio performance among sampled transit agencies over a six-year period (1985–1990) and transit industry compliance with the FTA 20% guideline. While quantitatively explaining the state of "what is," this analysis did not shed light on agency challenges to achieving a 20% spare ratio, nor did it provide recommendations or insights on how to improve.

In their three reviewed reports, Jaraiedi and Iskander (1989), Iskander et al. (1989), and Iskander and Jaraiedi (1988) provided an analytical framework for analyzing the ramifications of the FTA 20% guideline; and for developing methodologies by which different variables impacting the spare ratio can be analyzed. The methodologies and simulation models described are relatively simplistic, given their development in the late 1980s when transit fleets and service mixes were much less complex. However, there is much in the models that is still relevant, and that could potentially provide a foundation for new tools to inform today's transit agencies in their determination of the optimal number of spare buses.

CHAPTER THREE

SURVEY METHODOLOGY AND RESULTS: SYSTEM-SPECIFIC SPARE BUS RATIOS

This chapter describes the methodology and results of a comprehensive survey of transit agencies conducted for this TCRP synthesis to illuminate the current state of bus fleet spare ratios and related transit agency experiences, challenges, opportunities, and practices.

DESCRIPTION OF THE SURVEY METHODOLOGY

To achieve the objectives of this synthesis, an on-line survey questionnaire was developed that focused on the various attributes affecting spare bus needs and fleet spare ratios, and actions that agencies have implemented toward reducing their fleet spare ratios and their results. Questions were designed to gather information concerning agencies' bus fleet(s) used to deliver fixed-route and other scheduled general public transit services. This survey did not cover ADA paratransit services or vanpool vehicles. The survey questionnaire is reproduced in Appendix A.

A core sample of 48 transit agencies was developed based on: (1) geographic/climatic distribution; (2) bus fleet size; (3) past participation in the 1995 *TCRP Synthesis 11: System-Specific Spare Bus Ratios*; and (4) prior known interest in the topic. Five bus fleet size groupings were established for this survey: small fleets (25–99 buses); medium fleets (100–249 buses); large fleets (250–499 buses); very large fleets (500–999 buses); and mega-fleets (1,000 buses or more).

A link to complete the survey on-line was e-mailed to a contact person at each agency in the core sample. Telephone calls and/or e-mails were sent to agencies included in the core sample before and after survey distribution to identify the correct survey respondent and encourage prompt responses, followed by friendly reminders in the form of e-mails and/or phone calls.

If an agency indicated that it was unwilling or unable to respond, an alternate agency was identified (with similar fleet size and geographic attributes) and contacted. Information from APTA and other sources were used to identify and/or follow up with survey participants. The University of South Florida Center for Urban Transportation Research Bus Fleet Maintenance ListServe was also employed to identify potential survey participants as needed.

A total of 38 completed survey responses were received, tabulated, analyzed, and summarized for inclusion in this synthesis (a 79% response rate). Table 1 lists and organizes the respondents by geographic region and fleet size (with agency bus fleet size noted in parentheses).

Figure 1 graphically illustrates the distribution of the 38 respondents surveyed across fleet size groups and geographic regions. Of the 38 respondents, five (13%) were in the small fleets group; nine (24%) in the medium fleets group; seven (18%) in the large fleets group; nine (24%) in the very large fleets group; and eight (21%) in the mega fleets group. (It should be noted that within the mega-sized group, the New York City Transit Bus fleet is nearly twice the size of the next largest fleet, New Jersey Transit.)

Of the 38 respondents, the largest geographic representation reflected the most populous regions. The U.S.–Northeast, U.S.–Northwest (including Northern California), and the U.S.–Southwest (including Southern California) each had eight agencies (21%) reporting.

KEY FLEET ATTRIBUTES AMONG SURVEYED TRANSIT AGENCIES

The following section provides an overview of the key fleet attributes reported among the transit agencies surveyed, including service delivery model, annual vehicle-miles, bus fleet spare ratios, fleet mix diversity, and contingency fleets.

Agency Service Delivery Models

Survey respondents were asked to choose from the following classifications those that best described the agency's service delivery business model(s): either directly operated (and maintained) and/or contracted bus services. Agencies that delivered their transit services solely through direct operation (i.e., with in-house staff) represented 76% (29) of the survey respondents; agencies that utilized both direct operation and privately contracted services represented 16% (six) of the respondents; and agencies that delivered their transit services solely through contracting represented 8% (three) of the respondents. Table 2 summarizes this respondent distribution by service delivery model and fleet size group.

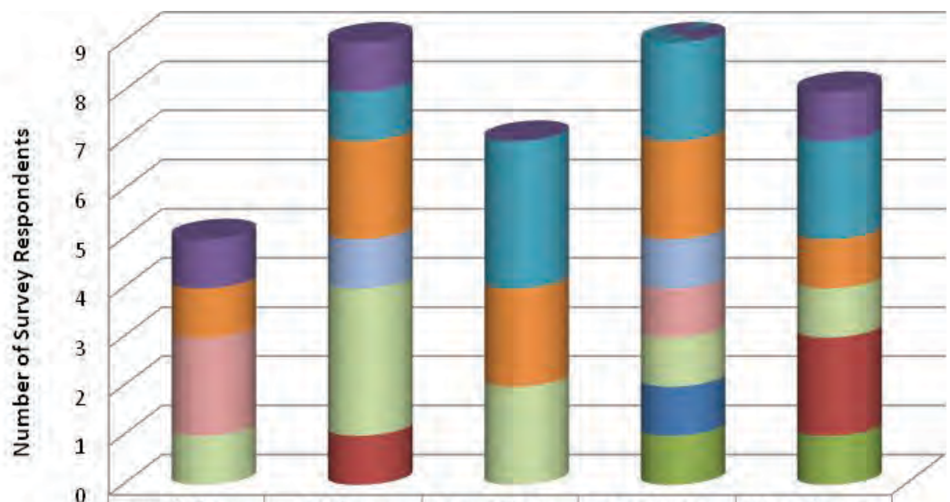
Annual Vehicle-Miles by Fleet Size

Survey respondents were asked to report their fleet's annual vehicle-miles. For agencies that have both directly operated

TABLE 1
PARTICIPATING U.S. AND CANADIAN TRANSIT BUS FLEETS BY SIZE AND GEOGRAPHIC REGION

Bus Fleets	25–99—Small	100–249—Medium	250–499—Large	500–999—Very Large	>1,000—Mega
U.S.					
North-Central	Connect Transit, Bloomington, IL(29)	CATA, Lansing, MI (96)	None	None	CTA, Chicago, IL (1,792)
Northeast	None	*Centro, Syracuse, NY (167)	*GCRTA, Cleveland, OH (452) *COTA, Columbus, OH (308) *RTA, Dayton, OH (263)	*PA Transit, Pittsburgh, PA (714) *MBTA, Boston, MA (910)	*NYCT MTA, NY (4,431) *NJ Transit ,NJ (2,382)
Northwest	VRT, Boise, ID (43)	Pierce Transit, Tacoma, WA (234) LTD, Eugene, OR (117)	*VTA, Santa Clara, CA (426) SamTrans, San Mateo, CA (287)	*Tri-Met, Portland, OR (594) *AC Transit, Oakland, CA (569)	*KC Metro, Seattle, WA (1,503)
South-Central	None	*RTA, New Orleans, LA (137)	None	*DART, Dallas, TX (644)	None
Southeast	StarMetro, Tallahassee, FL (67) Sumter County , FL (25)	None	None	*MDT, Miami, FL (818)	None
Southwest	CityBus, Culver City, CA (52)	RTA, Riverside, CA (171) LBT, Long Beach, CA (220) Sun Tran, Tucson, AZ (237)	RTC, Las Vegas, NV (397) *MTS, San Diego, CA (260)	OCTA, Orange County, CA (561)	*RTD, Denver, CO (1,003)
CANADA					
Central	None	None	None	Winnipeg Transit, MB (565)	None
East	None	London Transit, ON (192)	None	None	*TTC, Toronto, ON (1,857) STM, Montreal, QC (1,728)
West	None	None	None	Edmonton Transit, AB (972)	*Coast Mtn Bus, Vancouver (BC) (1,107)

*Participated in 1995 *TCRP Synthesis 11* Survey.
Note: Number of buses in each fleet is in parentheses (2012 reported).



	Small Fleets 25-99 Buses	Medium Fleets 100-249 Buses	Large Fleets 250-499 Buses	Very Large Fleets 500-999 Buses	Mega Fleets > 1000 Buses
US--North Central	1	1	0	0	1
US--Northeast	0	1	3	2	2
US--Northwest (incl. N. Calif)	1	2	2	2	1
US--South Central	0	1	0	1	0
US--Southeast	2	0	0	1	0
US --Southwest (incl. S. Calif)	1	3	2	1	1
Canada--Central	0	0	0	1	0
Canada--East	0	1	0	0	2
Canada--West	0	0	0	1	1

FIGURE 1 Distribution of the 38 survey respondents across bus fleet size groups and geographic regions.

TABLE 2
AGENCY DISTRIBUTION OF SERVICE DELIVERY MODELS BY FLEET SIZE GROUP

Service Delivery Model	Small Fleets 25–99 Buses	Medium Fleets 100–249 Buses	Large Fleets 250–499 Buses	Very Large Fleets 500–999 Buses	Mega Fleets >1,000 Buses	Total
Directly Operated Only	4	6	5	8	6	29
Directly Operated and Contracted	—	2	1	1	2	6
Contracted Only	1	1	1	—	—	3
Total	5	9	7	9	8	38

Source: Responses to Transit Agency Survey.

and contracted fleet operations, their fleets were combined. Table 3 summarizes the distribution of respondents by their 2012 annual vehicle-miles operated and fleet size grouping. Generally speaking, the larger the fleet, the greater the number of annual miles.

Agency Bus Fleet Spare Ratios

Survey respondents were asked to report their vehicles available for maximum service (VAMS), that is, their total active bus fleet; their vehicles operated in maximum service (VOMS); their peak bus fleet; and the fleet's spare bus ratio. Notably, responses indicated that surveyed agencies did not all use the same spare bus ratio definition specified by the FTA.

FTA guidelines state that for bus fleets, the basis for determining a reasonable spare ratio takes local circumstances into account. FTA specifies that the number of spare buses in the active fleet for grantees operating 50 or more fixed-route revenue vehicles is not to exceed 20% of the number of VOMS. The spare ratio is expressed as a percentage for example, 100 vehicles required and 20 spare vehicles is a 20% spare ratio. The FTA formula for calculating the spare ratio can be expressed as:

$$\text{Spare Ratio} = [\text{VAMS} - \text{VOMS}]/\text{VOMS}$$

FTA allows agencies to stockpile buses that have reached the end of their service lives in an inactive contingency fleet in preparation for emergencies. Such buses must be properly stored, maintained, and documented in a contingency plan. FTA specifically allows the exclusion of contingency fleet buses from the calculation of the spare ratio.

The spare ratio guideline is rooted in FTA policy as communicated through:

- FTA Circular C5010.1D, Chapter IV, Section 3i
- FTA Circular C9030.1C, Chapter V, Sections 9.a (5)-(6).

Since there was some variation among definitions used by responding agencies to compute their spare ratio, there needed to be a common basis upon which to analyze survey spare ratio data. To this end, the spare ratios reported were recomputed with the VAMS and VOMS data provided by the respondents, using the FTA formula. Table 4 further breaks down the fleets and their recomputed spare ratios by fleet size group, and separately for directly operated and contracted fleets.

Of the 35 directly operated fleets surveyed, 17 (49%) were within the 20% FTA spare ratio guideline, while an equal number exceeded the 20% threshold (with one non-response). Most of the directly operated fleets, 26 of 35 (74%), had spare ratios at or below 25%.

Looking at spare ratios by directly operated fleet size group, two of the six large fleets; five of the nine very large fleets; and five of eight of the mega-fleets had spare ratios at or near the FTA 20% spare ratio guideline. Generally speaking, the mega-fleets, with their access to greater financial resources and support infrastructure, may be able to operate with leaner spare ratios than smaller fleets. Of the nine contracted fleets surveyed, only three operated at a 20% ratio or below, while

TABLE 3
DISTRIBUTION OF THE NUMBER OF RESPONDENTS BY THEIR 2012 ANNUAL VEHICLE MILES OPERATED AND FLEET SIZE GROUPING (COMBINED DIRECTLY OPERATED AND CONTRACTED)

2012 Vehicle-Miles Operated	Small Fleets 25–99 Buses	Medium Fleets 100–249 Buses	Large Fleets 250–499 Buses	Very Large Fleets 500–999 Buses	Mega Fleets >1,000 Buses	Total
0 to 4,999,999	5	3	—	—	—	8
5,000,000 to 9,999,000	—	3	3	—	—	6
10,000,000 to 49,999,999	—	2	4	9	3	18
50,000,000 to 99,999,999	—	—	—	—	4	4
>100 million	—	—	—	—	1	1
Total	5	9	7	9	8	38

Source: Responses to Transit Agency Survey.

TABLE 4
DISTRIBUTION OF THE NUMBER OF RESPONDENTS BY THEIR COMPUTED 2012 SPARE BUS RATIOS AND FLEET SIZE GROUPING—FOR DIRECTLY OPERATED FLEETS AND CONTRACTED FLEETS

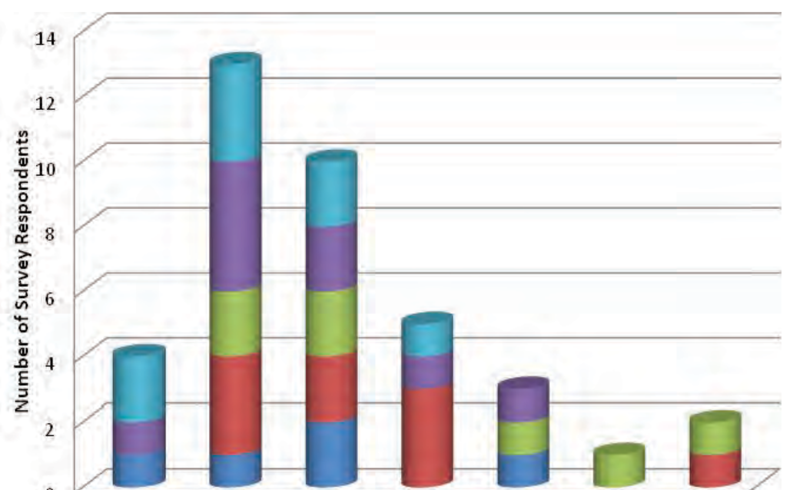
Spare Ratios	Small Fleets 25–99 Buses	Medium Fleets 100–249 Buses	Large Fleets 250–499 Buses	Very Large Fleets 500–999 Buses	Mega Fleets >1,000 Buses	Total
Directly Operated						
11%–15%	1	—	—	1	2	4
16%–20%	—	4	2	4	3	13
21%–25%	2	1	2	2	2	9
26%–30%	—	3	—	1	1	5
30%–39%	1	—	—	1	—	2
>40%	—	—	1	—	—	1
Not Reported	—	—	1	—	—	1
Total	4	8	6	9	8	35
Contract Operated						
11%–15%		—	—	—	1	1
16%–20%	1	—	1	—	—	2
21%–25%	—	1	—	—	—	1
26%–30%	—	—	—	1	1	2
30%–39%	—	1	1	—	—	2
>40%	—	—	—	—	—	0
Not Reported	—	1	—	—	—	1
Total	1	3	2	1	2	9

Source: Responses to Transit Agency Survey.

five of the nine fleets had a spare ratio larger than 20%. One of the nine contacted fleets did not supply sufficient data to calculate the spare bus ratio.

Figure 2 summarizes the distribution of respondents by their computed (2012) spare ratios and fleet size groups. The figure illustrates that the largest number of respondents, 13 of 38 (34%) had spare ratios between 16% and 20%; and another 10 respondents (26%) had spare ratios between 21% and 25%.

(In Canada, an agency's spare bus fleet spare ratio is purely a local decision. There is not a federal or provincial transportation entity comparable to the FTA that has a spare ratio target or guideline.)



	11-15% Spare Ratio	16-20% Spare Ratio	21-25% Spare Ratio	26-30% Spare Ratio	30-39% Spare Ratio	>40% Spare Ratio	Not Reported
Mega Fleets > 1000 Buses	2	3	2	1			
Very Large Fleets 500-999 Buses	1	4	2	1	1		
Large Fleets 250-499 Buses		2	2		1	1	1
Medium Fleets 100-249 Buses		3	2	3			1
Small Fleets 25-99 Buses	1	1	2		1		

FIGURE 2 Distribution of the number of respondents by their computed 2012 spare bus ratios and fleet size grouping—combining both directly operated and contracted fleets.

TABLE 5
DISTRIBUTION OF THE NUMBER OF RESPONDENTS BY FLEET SIZE GROUPINGS AND THEIR NUMBER OF SUB-FLEETS—FOR DIRECTLY OPERATED FLEETS ONLY

No. of Sub-fleets	Small Fleets 25–99 Buses	Medium Fleets 100–249 Buses	Large Fleets 250–499 Buses	Very Large Fleets 500–999 Buses	Mega Fleets >1,000 Buses	Total
1 Sub-fleet	—	2	—	—	2	4
2 Sub-fleets	1	2	—	4	—	7
3 Sub-fleets	2	2	3	2	3	12
4 Sub-fleets	1	1	1	3	2	8
5 Sub-fleets	—	1	2	—	—	3
6 Sub-fleets	—	—	—	—	1	1
Total	4	8	6	9	8	35

Source: Responses to Transit Agency Survey.

Looking at agency spare ratio trends over past five years, 16 of the 35 (46%) directly operated agency fleets were able to reduce their spare ratios from 2008 to 2012; 13 (37%) increased their spare ratio over this period; and five (14%) stayed the same.

Agency Fleet Mix Diversity

Over the years, transit fleets have become more diverse, containing different mixes of bus types or sub-fleets that have unique size, capacity, and operating attributes. The survey asked respondents to indicate how many of the following bus types were used as sub-fleets by their agencies:

- Less-than-30-foot buses
- 30-foot buses
- 35-foot buses
- 40-foot standard buses
- Over-the-Road (OTR) three-axle buses
- 60-foot articulated standard buses
- Double-decker buses
- Special mall shuttle buses (Denver only)
- Trolley buses (catenary).

Tables 5 and 6 summarize the distribution of respondents by fleet size groups and the number of sub-fleets they operate.

Of the 35 directly operated fleets surveyed, 24 (68%) had three or more different sub-fleets. Of the nine agencies with contract fleets, four had three or more sub-fleets, while five had only one or two.

By fleet size grouping, four of eight medium fleets and all six large fleets had three or more sub-fleets.

Agency Contingency Fleets

Agencies have the option of keeping a reserve contingency fleet. These are often older buses that are not available for revenue service, but can be held in an inactive status for non-revenue uses or rapid activation for emergency needs. Contingency fleet buses are not included in the FTA spare ratio formula (nor are they included in the 20% spare ratio guideline).

Although maintaining a contingency fleet can provide an agency with added flexibility for non-revenue activities, this flexibility comes at the cost of storing and maintaining these inactive vehicles. Eighteen of the 38 survey respondents (47%) reported that they maintained an inactive contingency fleet.

KEY VARIABLES AFFECTING SPARE RATIOS

The survey collected detailed information concerning some of the key variables that may have an effect on agency spare bus needs and spare ratios. The following section provides an overview of some of those key variables and survey

TABLE 6
DISTRIBUTION OF THE NUMBER OF RESPONDENTS BY FLEET SIZE GROUPINGS AND THEIR NUMBER OF SUB-FLEETS—FOR CONTRACTED FLEETS ONLY

No. of Sub-fleets	Small Fleets 25–99 Buses	Medium Fleets 100–249 Buses	Large Fleets 250–499 Buses	Very Large Fleets 500–999 Buses	Mega Fleets >1,000 Buses	Total
1 Sub-fleet	1	—	—	—	—	1
2 Sub-fleets	—	2	—	1	1	4
3 Sub-fleets	—	—	2	—	—	2
4 Sub-fleets	—	1	—	—	1	2
5 Sub-fleets	—	—	—	—	—	0
6 Sub-fleets	—	—	—	—	—	0
Total	1	3	2	1	2	9

Source: Responses to Transit Agency Survey.

responses to questions on fleet-related attributes and service and operating environmental attributes.

Survey respondents were asked to provide information concerning fleet-related attributes, including average age, the number of advanced on-board technologies in the fleet, and alternative fueling/energy technologies; and their impacts on their agency's spare vehicle needs and spare ratio levels.

Survey respondents were also asked to provide information concerning service and operating environmental attributes, which included agency service profiles and special vehicle features required, special or intermittent service requirements, peak-to-base ratios, unique climatic conditions, and duty cycles; and the impacts these factors had on agency's spare vehicle needs and spare ratio levels.

This overview is followed by a summary of survey responses reflecting the relative importance of each variable on the respondent's spare bus needs and fleet spare ratio.

Average Age

Of the 38 agencies surveyed, 23 (61%) had fleets with an average age between 6.0 and 8.9 years old. Only eight (21%) reported an average age of more than 8.9 years. Figure 3 summarizes the distribution of respondents by the average age of the buses in both directly operated and contract operated fleets

The survey then asked whether the average age or cumulative mileage of agencies' fleets affected their spare bus needs and fleet spare ratio. Of the 38 surveyed agencies, 22 (58%) indicated "Yes" while 16 (42%) responded "No."

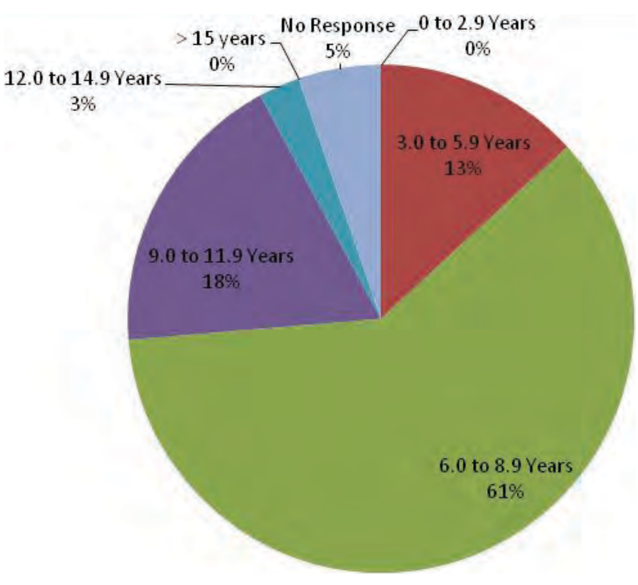


FIGURE 3 Distribution of number of survey responses by average bus fleet age—combined directly operated and contracted fleets.

Although counter-intuitive to the survey responses described earlier, further analysis of survey data did not indicate an appreciable correlation between the average age of an agency's fleet and its spare ratio. Figure 4 plots survey responses and depicts the correlation of a fleet's average bus age with spare ratios over time (for 2012, 2010, and 2008). Using regression analysis, a regression line was plotted for each of the three measured years and a coefficient of determination ("*r*-squared") was calculated. The r-squared is interpreted as the "goodness of fit" of a regression line. The higher the coefficient of determination (the closest to 1.0), the better the variance of the dependent variable (spare ratio) is explained by the independent variable (average bus age). In this case, the r-squared values for 2012, 2010, and 2008 (0.07, 0.03, and 0.01, respectively) demonstrated limited (statistical) explanatory value of average fleet age versus the spare ratio.

Given the relatively small sample size, caution would be advised in concluding that there is no appreciable correlation between the average age of an agency's fleet and its spare ratio. In their comments, many survey respondents indicated that as buses age, more maintenance (and downtime) is required to keep the vehicles in a state of good repair. Many indicated that older vehicles need more repair, and require longer repair times, as a result of corrosion and replacement part shortages, thus increasing the need for spare buses.

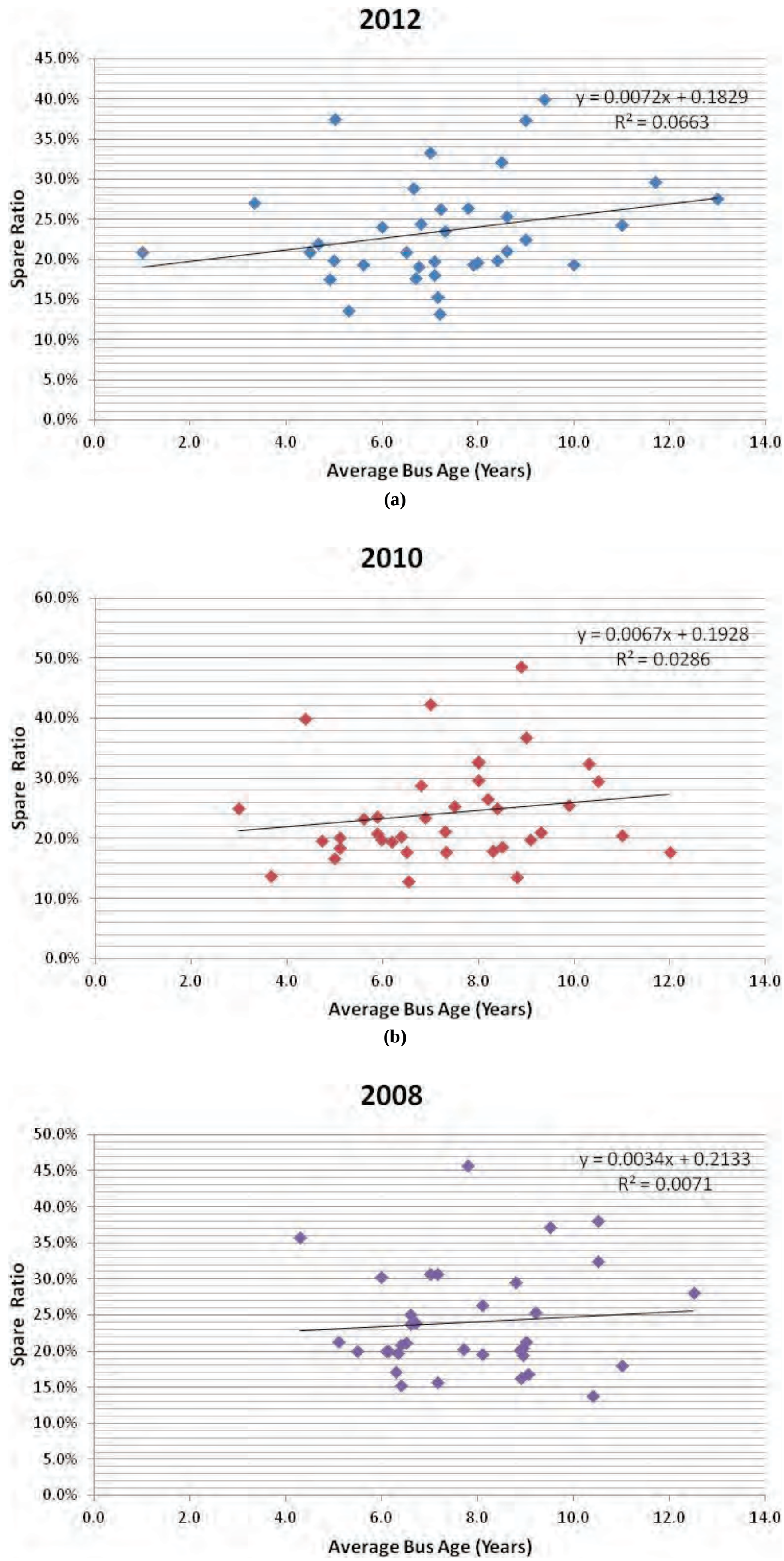
Advanced On-Board Technology

The survey asked respondents to indicate which of the following systems were present in their entire fleet:

- On-board electronic fare collection
- Automatic vehicle location (AVL)
- Bus stop enunciation
- Automatic passenger counters
- Digital radio communication
- Data transmission (including mobile data terminals)
- Wireless Internet access
- On-board surveillance
- Advanced emissions control
- Regenerative braking
- Electronic head signs
- Closed area networks
- Remote diagnostics
- Hazard detection/response systems.

Table 7 summarizes the distribution of respondents by the total number of advanced technology systems within their fleets.

Of the 38 agencies surveyed, 16 (42%) had either nine or 10 on-board advanced technology systems in their entire fleet. Twenty-five of the 38 respondents (66%) had more than eight on-board technology systems to maintain in their



(a) (b) (c)

FIGURE 4 Correlation of average bus age (years) with spare ratio over time—both directly operated and contracted fleets.

TABLE 7
DISTRIBUTION OF THE NUMBER OF RESPONDENTS BY THE NUMBER OF ADVANCED TECHNOLOGY SYSTEMS ON BOARD PRESENT WITHIN THEIR ENTIRE FLEET—BOTH DIRECTLY OPERATED AND CONTRACTED COMBINED

Number of Advanced Technology Systems on-Board Buses (2012)	Occurrences
0–2	1
3–4	2
5–6	5
7–8	4
9–10	16
11–12	5
13–14	3
15 +	1
No response or not applicable	1
Total	38

Source: Responses to Transit Agency Survey.

fleet. Only 12 of the 38 (32%) respondents had eight or fewer on-board technology systems to support.

The number of these systems appears to be increasing over past five years, though for some agencies this number has been stable.

The survey then asked respondents if the number of advanced on-board technology systems present in fleet affected their spare bus needs and fleet spare ratio. Of the 38 surveyed agencies, 19 (50%) responded "No" while an equal number indicated "Yes."

As with average bus age, analysis of reported survey data indicated a limited correlation between the number of advanced technology systems on board an agency's buses and its spare ratio. Figure 5 plots survey responses and depicts the correlation of the number of advanced technology systems present in the survey respondent's fleet with spare ratios over time (for 2012, 2010, and 2008). Using regression analysis, a regression line was plotted for each of the three years and the coefficient of determination ("*r*-squared") was calculated. In this case, the *r*-squared values for 2012, 2010, and 2008 (0.04, 0.03, and 0.02, respectively) demonstrate limited explanatory value of the number of on-board advanced technology systems versus the spare ratio.

Again, given the relatively small sample size, caution would be advised in concluding that there is no appreciable correlation between the number of advanced technologies in an agency's fleet and its spare ratio. In their comments, several survey respondents reported that the advanced technologies on board buses in their fleets require downtime for repairs, have additional lead times for parts, and necessitate more frequent maintenance and servicing (which results in increased labor hours). Respondents also indicated that presence (or lack) of these systems may affect the scheduled and unscheduled maintenance work, training, vendor maintenance, or other issues requiring spare buses, therefore, directly and/or indirectly, impacting their spare ratios.

Alternative Fueling/Energy Technologies

The survey asked respondents to indicate which of the following fuel/energy systems were employed in their combined fleet:

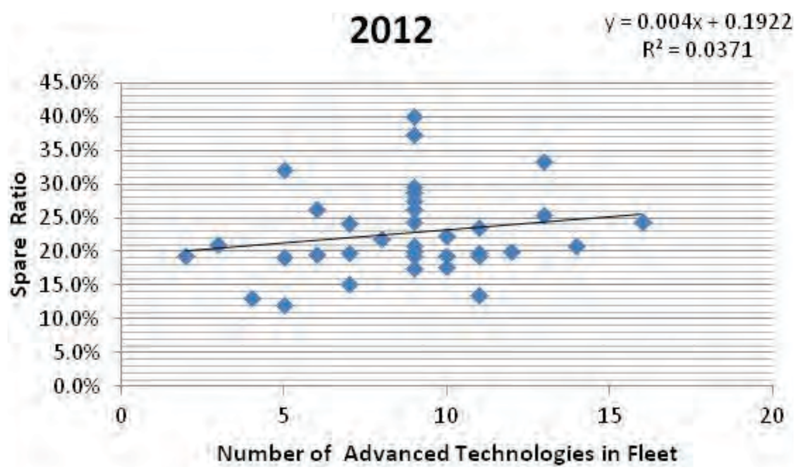
- Gasoline
- Diesel
- Compressed natural gas (CNG)
- Liquified natural gas
- Propane
- Hybrid-electric (gasoline)
- Hybrid-electric (diesel)
- Battery-electric
- Fuel cell
- Electric trolley (catenary)
- Other.

Table 8 summarizes the fuel/energy propulsion systems represented among the surveyed agency fleets and the frequency of use.

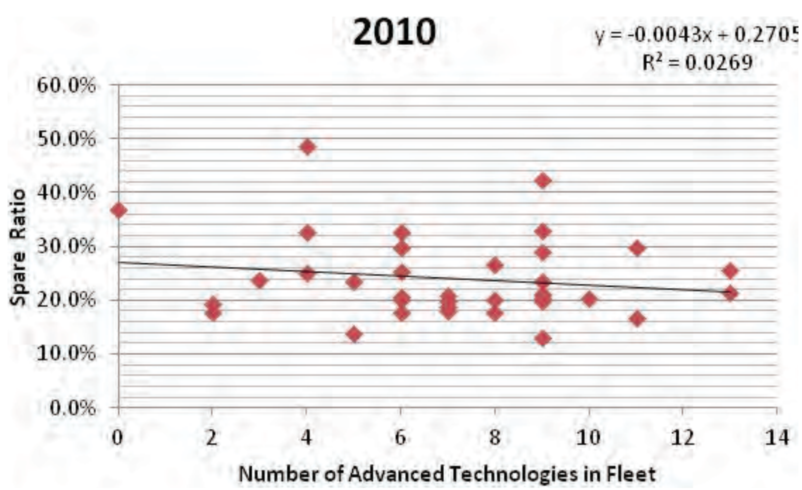
Clearly, diesel continues to be the predominant fueling and propulsion system for buses in the respondent fleets. Diesel buses are used by 35 of the 38 agencies responding (92%); followed in frequency by hybrid-electric buses, present in 24 fleets (63%); and CNG buses, present in 17 fleets (45%).

Only five agencies (13%) were exclusively diesel-powered. The number of buses operated with an alternative fuel/energy system appears to have increased over the past five years. Many agencies are experimenting with hybrid and other technologies by introducing and, where successful, incrementally expanding their alternatively-powered fleets.

The survey then asked respondents if the fuel/energy propulsion systems used by their fleet affected their spare bus needs and spare ratio. Of the 38 surveyed agencies, 21 (55%) responded "No," whereas 16 (42%) indicated "Yes" (with one non-response).



(a)



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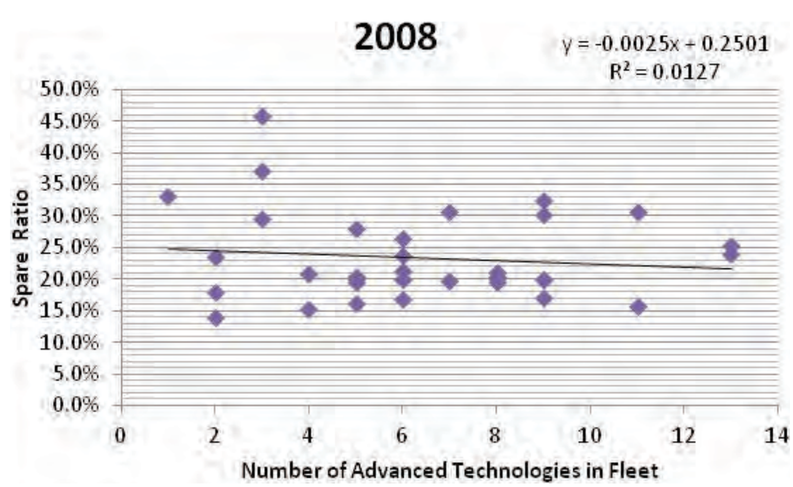

(c)

FIGURE 5 Correlation of number of advanced technology systems in the fleet with its spare ratio over time—both directly operated and contracted fleets.

TABLE 8
OCCURRENCES OF DIFFERENT FUEL/ENERGY PROPULSION SYSTEMS AMONG RESPONDENT BUS FLEETS—BOTH DIRECTLY OPERATED AND CONTRACTED

Presence of Fuel/Energy System in Respondent Fleets in 2012	Occurrences
Gasoline	6
Diesel	35
Compressed Natural Gas (CNG)	17
Liquefied Natural Gas (LNG)	2
Hybrid-Electric (diesel and gasoline)	24
Fuel Cell	1
Electric Trolley (overhead catenary)	4

Source: Responses to Transit Agency Survey.

There did not appear to be any strong correlation patterns between the presence of particular fueling/energy systems and spare ratios. Table 9 depicts the fuel/energy systems reported within agency fleets, cross-tabbed by the agency spare ratio category. All fuel/energy types could be found in fleets at all spare ratio levels.

Agency Service Profiles

The survey asked respondents to indicate which of the following transit service types their agency delivers with its combined fleets:

- Bus rapid transit (BRT)
- Commuter express (non-BRT)
- Regional trunk
- Local route
- Neighborhood circulator/feeder
- Shuttle
- Other.

Clearly, local routes continue to be the predominant category of service type delivered by buses in the respondent fleets, as all 38 agencies provide this type of service (Table 10). The second most frequent service was neighborhood circulator/feeder service, provided by 24 agencies (63%); followed by non-BRT service commuter express (23 agencies, or 60%); shuttle services (15 agencies, or 39%); and BRT by 14 agencies (37%).

The survey then asked respondents if the types of services provided by their agencies affected spare bus needs or fleet spare ratio. Of 38 agencies, 22 (58%) responded "No," while 16 (42%) indicated "Yes."

Special Vehicle Needs

The survey asked respondents to indicate which of the following special vehicle features are essential to providing particular types of agency transit services:

- High passenger-carrying capacity (more than a standard 40-ft bus)
- Special exterior branding with unique paint scheme
- Exterior wood trim (e.g., for trolley replicas)
- Ability to maneuver in confined areas
- Luggage racks/storage
- Premium seating and other interior amenities
- Low floor
- More than one door
- Other.

Table 11 tallies the essential vehicle features that are critical to the effective delivery of the mix of an agency's services, and the frequency of representation.

TABLE 9
OCCURRENCES OF DIFFERENT FUEL/ENERGY PROPULSION SYSTEMS AMONG RESPONDENT BUS FLEETS CROSS-TABBED BY SPARE RATIO CATEGORY—COMBINED DIRECTLY OPERATED AND CONTRACTED

2012 Spare Ratio Combined Directly Operated and Contracted	Occurrences of Fuel/Energy System in Respondent Fleets						
	Gasoline	Diesel	CNG	LNG	Hybrid (diesel-hybrid or gasoline hybrid)	Fuel Cell	Electric Trolley (overhead catenary)
11%–15%	1	4	2	—	2	—	—
16%–20%	2	13	6	—	9	1	2
21%–25%	2	9	4	2	6	—	1
26%–30%	1	5	2	—	3	—	—
30%–39%	—	2	3	—	2	—	—
>40%	—	2	—	—	2	—	1
Total	6	35	17	2	24	1	4

TABLE 10
SUMMARIZES THE TRANSIT SERVICE TYPES REPRESENTED AMONG THE SURVEYED AGENCY FLEETS AND THE FREQUENCY OF REPRESENTATION—OCCURRENCES OF DIFFERENT TRANSIT SERVICE TYPES DELIVERED BY RESPONDENT BUS FLEETS—BOTH DIRECTLY OPERATED AND CONTRACTED

Transit Service Types Delivered by Respondent Bus Fleets in 2012	Occurrences
Bus Rapid Transit (BRT)	14
Commuter Express (non-BRT)	23
Regional Trunk	10
Local Route	38
Neighborhood Circulator/Feeder	24
Shuttle	15
Other	4

Source: Responses to Transit Agency Survey.

The most frequently reported essential feature was more than one door, reported by 29 of the 38 agencies (76%); followed by a low floor (reported by 28 agencies, or 74%); and special exterior branding, listed by 25 agencies (66%). Important, but less frequently noted, were high capacity (19 agencies, or 50%), and premium seating and luggage racks/storage (each listed by 13 agencies, or 34%).

The survey then asked respondents if the lack of available buses equipped with these specialized features affected their ability to meet daily pullout requirements of any services. Of the 38 surveyed agencies, 27 (71%) responded "No," whereas 10 (26%) indicated "Yes" (with one responding "not applicable").

Special or Intermittent Service Needs

The survey asked respondents to indicate which of the following services their fleet is called upon to deliver in addition to regular service:

- Special event or exhibition transportation
- Back-up "bus bridges" in case of rail interruptions
- "Plug buses" for overloads and/or schedule compliance/ "catch-up"
- Training
- Other emergency or special need
- None of the above or not applicable.

Table 12 summarizes the types of special or intermittent services needs as represented among the surveyed agency fleets.

The most frequently reported special or intermittent service needs requiring bus fleet support are training (32 of 38 agencies, or 84%) and special events/exhibitions (31 agencies, or 82%). Important, but less frequently mentioned, are other emergency or special needs (24 agencies, or 63%); and plug buses and back-up bus bridges, each reported by 23 agencies (60%).

The survey then asked respondents whether meeting these special or intermittent service requirements affected their spare vehicle needs and spare ratio. Twenty-two agencies (58%) responded "No," whereas 15 (39%) indicated "Yes" (with one non-response).

TABLE 11
OCCURRENCES OF DIFFERENT ESSENTIAL VEHICLE FEATURES THAT MUST BE AVAILABLE ON VEHICLES IN RESPONDENT BUS FLEETS—BOTH DIRECTLY OPERATED AND CONTRACTED

Essential Vehicle Features That Are Needed to Effectively Deliver an Agency's Mix of Transit Services	Occurrences
High passenger-carrying capacity more than a standard 40-ft bus	19
Special exterior branding with unique paint scheme	25
Exterior wood trim (e.g., for trolley-replicas)	2
Ability to maneuver in confined areas	10
Luggage racks/storage	13
Premium seating and other interior amenities	13
Low floor	28
More than one door	29
Other	5
None	1

Source: Responses to Transit Agency Survey.

TABLE 12
TYPES OF SPECIAL OR INTERMITTENT SERVICES NEEDS THAT MUST BE SUPPORTED BY VEHICLES IN RESPONDENT'S BUS FLEETS—BOTH DIRECTLY OPERATED AND CONTRACTED

Special or Intermittent Services Needs	Occurrences
Special Event or Exhibition	31
Back-Up "Bus Bridges" for Rail Interruptions	23
"Plug Buses" for Overloads and/or Schedule Compliance/"Catch-up"	23
Training	32
Other Emergency or Special Need	24
None of the Above or Not Applicable	2

Source: Responses to Transit Agency Survey.

Peak-to-Base Ratios

The peak-to-base ratio is a measure of the amount of non-revenue time between the peak periods that buses may be available for PM inspections and other necessary maintenance activities. The survey asked respondents the greatest number of buses required for service during the a.m. and p.m. peak periods and the smallest bus requirement during the base period—i.e., the off-peak period in between the a.m. and p.m. peak periods. Responses and the calculated peak-to-base ratios are detailed in Appendix D (available on-line only).

The survey then asked respondents if their agency's peak-to-base ratio, and the resulting available bus maintenance time window, affected their spare bus needs and fleet spare ratio. Of the 38 agencies, 23 (60%) responded "No," while 14 (37%) indicated "Yes" (with one non-response).

Unique Climatic Conditions and other Operating Factors

Respondents were asked to indicate which of the following unique climatic or other environmental conditions their agency operates transit services under:

- Extreme heat
- Extreme humidity
- Extreme cold
- Heavy snow and/or ice
- Salt or other corrosive elements
- Steep hills
- Extremely rough pavement
- Other.

The responses of the surveyed agencies on the conditions each agency reported are detailed in web-only Appendix D.

The survey then asked whether these conditions in their service area affected spare vehicle needs and fleet spare ratio. Nineteen of the 38 agencies (50%) responded "No," while 15 (39%) indicated "Yes" (with four "not applicable").

Duty Cycles

The survey asked respondents to indicate the relative proportion of its bus operations that fall within three intensity levels of duty cycles:

- Heavy (intensive stop/start/dwell)
- Medium (moderate stop/start/dwell)
- Light (infrequent stop/start/dwell).

Responses are detailed in web-only Appendix D.

Respondents were then asked whether duty cycles affected spare bus needs and fleet spare ratio. Twenty-six (68%) responded "No," while 10 (26%) reported "Yes" (with two "no response").

Fleet, Service, and Operations: Relative Influence on Required Spare Buses

The survey asked respondents to indicate the relative degree to which each factor listed here influences the number of spare buses that their agency is required to maintain:

- Alternative fuel/energy systems in fleet
- Special vehicle needs or features required on certain routes
- Age or mileage of the fleet
- Advanced on-board technology systems
- Intensity of duty cycles
- Requirements to meet special service demands (e.g., emergencies, rail interruption support, "plug" buses for overloads or schedule catch-up, etc.)
- Peak-to-base ratio (and resulting available bus maintenance time window)
- Other (if not listed, refer to next question).

Each of the respondents was asked to rate the relative influence of each factor on a scale of zero to four:

- 4—Significant influence
- 3—Moderate influence

- 2—Limited influence
- 1—No influence
- 0—Not applicable.

The result was a weighted ordering of each factor in terms of its relative influence on the number of spare buses that the collective survey respondents are required to maintain (see Table 13).

According to the weighted scores provided by the survey respondents, two factors appear to have the greatest influence on the number of spare buses that are required to support an agency's services and maintenance requirements: (1) the age/mileage of the fleet, with a weighted score of 112; and (2) the intensity of duty cycles, with a weighted score of 100. The next most influential factors are peak-to-base ratio and available service window—each with a weighted score of 90—and special vehicle needs, with a weighted score or 89.

AGENCY FLEET MAINTENANCE PROGRAMS

Surveyed agencies were asked to provide information concerning their fleet maintenance programs, which may have an effect on (and be affected by) their spare bus needs and spare ratio. The following section provides an overview of some of those key variables and survey responses to questions on agency fleet maintenance programs.

Survey respondents were asked to provide information concerning maintenance program attributes, including: level of maintenance staffing; training and unmet needs; fleet replacement/rehabilitation programs; out-of-service criteria; maintenance facility and depot constraints; fleet reliability; and ongoing maintenance activities.

Following is a summary of reported results. This is followed by a summary of survey responses reflecting the relative importance of each attribute on the agency's spare bus needs and fleet spare ratio.

Level of Maintenance Staffing

Respondents—including technicians who actually work on the vehicles and their systems and sub-systems, but not fuelers, cleaners, tire-servicers, etc.—were asked to compute the ratio of technicians to buses. Responses were provided in different formats, making comparisons difficult. Each survey response to this question is detailed in web-only Appendix D.

Level of Training and Unmet Needs

The survey requested information concerning the type of training that is regularly provided to agencies' maintenance staff, including in-house, manufacturer/vendor supported, and other outsourced training.

The survey also requested information concerning any training needs that are not being addressed and why. Following are some of the responses received to the latter question:

- Electronic training on vehicle wiring; anti-lock systems training
- Soft skills (computer, windows, memo-writing skills, record keeping), owing to lack of funding and schedule conflicts to maintain the required numbers of buses
- Hybrid-electric maintenance training owing to lack of available trainers at the original equipment manufacturer level; limited employee training availability during peak service times
- Budget constraints have tightened training sessions as a result of limitations on internal training staff availability when doing training.
- Some vendor and major component training is missed as a result of lack of manpower to back-fill while in training.
- Frequency of training and refresher training because of a lack of staff to back-fill
- Not enough staff to back-fill technicians while in training. Training space is used for vehicle maintenance/repair/retrofits.
- Quality assurance is not addressed because of a lack of training staff.

TABLE 13
RELATIVE ORDERING OF FACTORS INFLUENCING AGENCY SPARE BUS NEEDS

Factors Impacting Spare Bus Needs	Weighted Score	Relative Order of Influence (#1 = greatest influence, #7 = least influence)
Age or Mileage of Fleet	112	1
Intensity of Duty Cycle	100	2
Peak/Base Ratio and Available Service Window	90	3
Special Vehicle Needs	89	4
Advanced On-Board Technology	85	5
Alternative Fuel/Energy Systems	83	6
Requirements to Meet Special Service Demands	82	7
Other	15	8

Source: Responses to Transit Agency Survey.

TABLE 14
RESPONSE TO WHETHER OR NOT AGENCY HAS AN ESTABLISHED BUS REPLACEMENT AND/OR REHABILITATION SCHEDULE

Response	Replacement Schedule	Rehabilitation Schedule
Yes (for Heavy-Duty *and* Medium/Light-Duty Buses)	16	2
Yes (for Heavy-Duty Buses Only)	18	15
No (neither Heavy-Duty nor Medium/Light-Duty Buses)	4	18
No Response	0	3
Total	38	38

Source: Responses to Transit Agency Survey.

Fleet Replacement Rehabilitation Schedule

The survey asked respondents whether their agency has an established bus replacement and/or major rehabilitation schedule for:

- Heavy-duty large buses (30-ft to 48-ft, and 60-ft articulated)
- Medium-to-light-duty small buses (16-ft to 30-ft, including cutaways).

The responses are summarized in Table 14. Detailed information on the specific schedules reported by agencies and further clarifying background they provided is contained in web-only Appendix D.

Thirty-four of the 38 respondents (89%) indicated they have an established fleet replacement schedule, although many also expressed that adhering to the schedule was contingent on available funding. At 18 of 38 agencies (47%), a schedule was set for the replacement only of heavy-duty coaches; 16 (42%) had a replacement schedule for both heavy-duty buses and medium/light-duty vehicles.

Seventeen respondents (45%) indicated they have an established fleet rehabilitation schedule. The schedule was applicable to the rehabilitation of heavy-duty coaches *only* for 15 of the 38 (39%) agency fleets; only two of 38 (5%) had a rehabilitation schedule for both heavy-duty buses *and* medium/light-duty vehicles.

Out-of-Service Criteria

The survey queried respondents concerning the criteria under which a bus is pulled from service, as one of the factors that may influence spare bus requirements. Respondents were asked to indicate which of the following out-of-service criteria they apply through policy or procedure:

- Any defect that precludes the safe operation of the bus
- Any defect that limits the accessibility of the bus (malfunctioning lift, ramp, kneeling mechanism, etc.)
- Any defect that adversely affects customer comfort (e.g., malfunctioning air conditioning or heating system)
- Any cosmetic damage or blemish (body dents, graffiti, scratched windows, torn seat, etc.)
- Lack of cleanliness (based on acceptable agency standard)
- Any defect that limits the collection of revenue (malfunctioning fare box, smartcard reader, etc.)
- Any defect that limits customer information (e.g., malfunctioning head-signs, automated stop announcement)
- Other.

The responses are summarized in Table 15. Detailed information on the specific out-of-service criteria reported by each agency is contained in web-only Appendix D.

The most frequently reported out-of-service criteria are defects that preclude or limit safe operation (all 38 agencies); accessibility (34 agencies, or 89%); and customer comfort

TABLE 15
TABULATION OF OUT-OF-SERVICE CRITERIA WITH WHICH TO PULL SUB-STANDARD BUSES FROM REVENUE SERVICE—BOTH DIRECTLY OPERATED AND CONTRACTED

Out-of-Service Criteria	Occurrences
Any defect that precludes the safe operation of the bus	38
Any defect that limits the accessibility of the bus (e.g., malfunctioning lift, ramp, kneeling mechanism, etc.)	34
Any defect that adversely affects customer comfort (e.g., malfunctioning air conditioning or heating system)	32
Lack of cleanliness (based on acceptable agency standard)	25
Any defect that limits the collection of revenue (e.g., malfunctioning farebox, smartcard reader, etc.)	22
Any defect that limits customer information (e.g., malfunctioning head-signs, automated stop announcement	19
Any cosmetic damage or blemish (e.g., body dents, graffiti, scratched windows, torn seat (etc.)	7

Source: Responses to Transit Agency Survey.

(32 agencies, or 84%). Important, but less frequently listed, were lack of cleanliness (25 agencies, or 66%); inability to collect revenue (22 agencies, or 58%); and impaired customer information (19 agencies, or 50%).

Fleet Reliability

The survey requested information from respondents concerning the reliability of their directly operated and contracted fleets, as measured by the average annual mean distance between mechanical failures. Respondents were asked to provide these data for five years (2008–2012).

The survey also asked the respondents for the definition of mechanical failure they used for the purpose of their calculations. There was a wide range of definitions used, making comparisons of the data difficult. There were also no discernible trends that could be discerned from the data regarding increased or decreased reliability. Appendix D (web-only) contains each agency's survey response with their reported fleet reliability data over the five-year period, along with the definition used.

Maintenance Facility/Depot Constraints

The survey requested information from respondents concerning any physical constraints at their maintenance facilities or depots that limit the functionality or flexibility of their maintenance activities as one of the factors that may influence spare bus requirements. Respondents were asked to indicate which of the following constraints are present:

- Limited number of maintenance bays or lifts
- Inability to support certain bus types (e.g., articulated buses, CNG fueling, etc.)
- Need to shuttle vehicles between facilities for certain maintenance needs (e.g., major component overhaul, PMs, paint/body, etc.)
- None.

The responses are summarized in Table 16. Detailed information on the specific physical constraints at their maintenance facilities as reported by each agency is contained in web-only Appendix D.

Twenty-one of the 38 (55%) survey respondents pointed to constraints associated with a limited number of maintenance bays and a need to shuttle vehicles between facilities. Eighteen of 38 (47%) reported the inability to support certain bus types as a constraint; and 17 (45%) complained of the need to shuttle vehicles between facilities for certain maintenance operations. Nine of 38 (24%) reported no facility constraints.

The survey also asked respondents if these facility constraints affected their spare vehicle needs and fleet spare ratio. Of the 38 surveyed agencies, 24 (63%) responded "No," whereas nine (27%) indicated "Yes" (the remaining five responded "not applicable").

Maintenance Program: Relative Influence on Required Spare Buses

The survey requested respondents to indicate the relative degree to which each maintenance program factor listed here influences the number of spare buses that their agency is required to maintain:

- Level of maintenance staffing in key skill areas
- Level of training
- Fleet replacement/rehab schedule
- Out-of-service criteria (when bus is removed)
- Fleet reliability (measured by mean distance between mechanical failures)
- Maintenance facility constraints (at one or more garages/depots).

Each of the respondents was asked to rate the relative influence of each factor on a scale of zero to four (with zero indicating the factor was not applicable to that agency):

- 1—No influence
- 2—Limited influence
- 3—Moderate influence
- 4—Significant influence.

The result was a weighted ordering of each factor in terms of its relative influence on the number of spare buses that the collective respondents are required to maintain (see Table 17).

TABLE 16
CONSTRAINTS LIMITING FUNCTIONALITY AT MAINTENANCE FACILITIES

Constraint	Occurrences
Limited number of maintenance bays or lifts	21
Inability to support certain bus types (e.g., artics, CNG fueling, etc.)	18
Need to shuttle vehicles between facilities for certain maintenance needs (e.g., major component overhaul, PMs, paint/body, etc.)	17
None	10

Source: Responses to Transit Agency Survey.

TABLE 17
RELATIVE ORDERING OF MAINTENANCE PROGRAM FACTORS INFLUENCING AGENCY SPARE BUS NEEDS

Relative Ranking of Factors Influencing Spare Bus Needs	Weighted Score	Relative Order of Influence (#1 = greatest influence, #5 = least influence)
Out-of-Service Criteria	100	1 (tie)
Fleet Replacement/Rehab Schedule	100	1 (tie)
Level of Training	97	2
Level of Maintenance Staffing in Key Skill Areas	96	3
Fleet Reliability	95	4
Maintenance Facility Constraints	73	5

Source: Responses to Transit Agency Survey.

According to the weighted scores provided by the survey respondents, the first five of these six factors have similarly strong influences on the number of spare buses that are required to support an agency's services and maintenance requirements. Out-of-service criteria and fleet replacement/rehab schedule both had a weighted score of 100; level of training had a weighted score of 97; maintenance staffing had a weighted score of 96; and fleet reliability a score of 95. Maintenance facility constraints had far less impact, with a weighted score of only 73.

On-Going Maintenance Activities: Relative Influence on Required Spare Buses

The survey asked respondents to indicate the relative degree to which each on-going maintenance activity listed here influences the number of spare buses that their agency requires:

- PM inspections/resulting actions
- Major component rebuild
- Scheduled midlife overhauls
- Minor/routine repair (i.e., running repair)
- Body and paint
- Daily servicing.

Survey respondents were then asked to rate the relative influence of each factor above on a scale of zero to four, with zero indicating not applicable:

- 1—No influence
- 2—Limited influence
- 3—Moderate influence
- 4—Significant influence.

The result was a weighted ordering of each factor in terms of its relative influence on the number of spare buses that the collective survey respondents are required to maintain (see Table 18).

According to the weighted scores provided by the survey respondents, three factors appear to have the greatest influence on the number of spare buses required to support an agency's revenue transit services and maintenance requirements: PM inspections/resulting actions with weighted score of 113; major component rebuild with a score of 112; and running repair with a score of 108. The next factors drop off significantly in scoring, and their relative influence on the spare fleet: body and paint (with a weighted score of 94); scheduled mid-life overhauls (75); and daily servicing (65).

OTHER FACTORS AND CHALLENGES

The survey also collected detailed information concerning some of the other factors and challenges that may have an effect on agency spare bus needs and spare ratios. The following section provides an overview of survey responses to questions concerning financial challenges; compliance with FTA spare ratio guidelines; Canadian funding impacts; agency spare ratio sufficiency; steps taken and solutions implemented; and suggested changes in policy and practices.

TABLE 18
RELATIVE ORDERING OF ON-GOING MAINTENANCE ACTIVITIES INFLUENCING AGENCY SPARE BUS NEEDS

Relative Ranking of Influences on Spare Bus Needs	Weighted Score	Relative Order of Influence (#1 = greatest influence, #6 = least influence)
PM Inspections/Resulting Actions	113	1
Major Component Rebuild	112	2
Running Repair	108	3
Body and Paint	94	4
Scheduled Mid-life Overhauls	75	5
Daily Servicing	65	6

Source: Responses to Transit Agency Survey.

TABLE 19
TABULATION OF SPECIFIC FINANCIAL CHALLENGES

Specific Financial Challenges Affecting Spare Ratios	Occurrences
Reduced capital dollars available for needed bus replacement	19
Reduced maintenance staffing levels	16
Transit service reductions resulting in unused vehicles (and expansion of the spare vehicle fleet)	13
Reduced funds available for state of good repair	9
Reduced dollars available for needed training	7
No financial challenges affecting spare ratios	16

Source: Responses to Transit Agency Survey.

Financial Challenges

The survey asked respondents whether financial challenges have affected their agency's spare bus needs and spare ratio. Of the 38 survey respondents, 22 (58%) replied "Yes" and 16 (42%) responded "No."

The survey then asked respondents to indicate whether their agency has experienced the following specific financial challenges:

- Reduced maintenance staffing levels
- Reduced capital dollars available for needed training
- Transit service reductions resulting in unused vehicles (and expansion of the spare vehicle fleet)
- Reduced capital dollars available for needed bus replacement
- Reduced funds available for state of good repair.

The responses are summarized in Table 19.

Nineteen (19) of the 38 (50%) survey respondents identified reduced capital dollars for needed bus replacement as the primary factor affecting agency spare bus needs and spare ratios; 16 (42%) pointed to reduced maintenance staffing levels as having the greatest impact; and 13 (34%) identified transit service reductions resulting in unused vehicles.

In addition to those challenges, other financial issues were mentioned by survey respondents:

- On-going funding challenges have changed service levels, spare ratios, and staffing levels.
- Must keep buses past their 12-year useful life; these older buses have a lower MDBF (mean distance between failures) and are out of service more often.
- Vehicle condition standards have been lowered and deferred maintenance on the rise.
- There have been no employee pay raises for three years and increased contributions towards benefits (pension and health).

Compliance with FTA Spare Ratio Guidelines

The survey asked respondents if their agency had exceeded the FTA's 20% spare ratio guideline in any of the past five years. Nineteen of the 38 (50%) surveyed agencies responded "Yes," while an equal number answered "No."

Of those agencies that responded "Yes," nine indicated that they were required to submit an action plan to the FTA specifying how they planned to get to a 20% spare ratio level. Two agencies reported that they had received "an annual conditional waiver." One agency mentioned that the "FTA provided an exemption that expires this federal fiscal year," and another responded that "communication between FTA and the agency [had] resolved the issue of exceeding the spare ratio threshold."

Canadian Funding Impacts

The survey asked Canadian respondents if there have been any impacts of federal and/or provincial funding on their agency's spare ratio. Table 20 summarizes their responses.

As previously noted, an agency's spare bus fleet spare ratio is purely a local matter in Canada. There is not a comparable federal or provincial organization (such as the FTA in the United States) that has a spare ratio target or guideline.

Agency Spare Ratio Sufficiency

The survey asked respondents if their current spare ratio was sufficient to meet the agency's maximum operating requirements and their optimal maintenance program. Twenty-one (21) of the 38 (55%) surveyed agencies responded "Yes," whereas 17 of the 38 (45%) answered "No."

Among reasons reported by those that responded "No" are:

- Overall budget constraints limiting the number of required maintenance staff positions, the availability of needed training, and retirement of older buses at the end of their useful life.
- The high average age of the fleet and resulting lack of reliability of revenue buses and spares.
- Advanced propulsion technologies and high-tech on-board equipment are more complex and maintenance intensive—and in some cases (e.g., gasoline-hybrids) more unreliable—drawing on the spare bus fleet.

TABLE 20
SUMMARY OF RESPONSES REGARDING IMPACTS OF FEDERAL AND/OR PROVINCIAL FUNDING LEVELS ON SPARE RATIOS

Agency	Impact(s)
London Transit (Ontario)	No significant impact.
Winnipeg Transit (Manitoba)	Improved funding from gas tax and other programs has allowed Winnipeg's fleet replacement program of 30 to 31 buses purchased per year to be uninterrupted for over ten years.
Edmonton Transit (Alberta)	In the past, there has been sufficient capital funding for fleet replacement and bus refurbishment. In the future, however, more limited capital dollars are expected for bus replacement and refurbishment with resulting challenges in fleet management.
Coast Mountain Bus, Vancouver (British Columbia)	On-going funding challenges at provincial/regional governmental levels have reduced spare ratios, service and staffing levels.
STM, Montreal (Quebec)	No impact.
Toronto Transit Commission (Ontario)	TTC relies on city/provincial/federal funding partners for financial support to maintain a safe and reliable bus fleet. There have been no notable or significant financial challenges that have impacted the fleet spare ratio over the last few years.

Source: Responses to Transit Agency Survey.

- Challenges in meeting preventive maintenance inspection/repair intervals while meeting revenue service bus pullout requirements.
- Challenges in attracting and retaining qualified technicians, etc.
- Difficulty in obtaining needed parts can delay getting buses out of the shop and back in service (and freeing up spare buses).
- Lack of sufficient spare buses and staffing to address long-term repairs, bus retrofits, equipment installation, special campaigns, fleet-wide defects, decommissioning, corrosion damage, and non-routine maintenance requirements.
- The mix of multiple specialty sub-fleets needed to support different service designs [and resulting] requirements for unique vehicle characteristics prevent inter-operability between sub-fleets and can limit the use of available spare buses.
- Demands for spare buses to support special services and training bus needs in addition to regular revenue pullout have resulted in a reduction in available repair time.

Steps Taken and Solutions Implemented

The survey asked respondents if their agency has been able to reduce its spare ratio over the past five years. Eighteen (18) of the 38 (47%) surveyed agencies responded "Yes," whereas 20 of the 38 (53%) answered "No."

Among actions taken to accomplish this reduction reported by those agencies that responded "Yes" are:

- Acquisition of newer vehicles (reducing the average fleet age) to improve vehicle reliability and availability
- Obtaining corporate commitment to a leaner fleet (and the resources required to accomplish this)
- Standardizing of the fleet, with fewer unique sub-fleets and specialized vehicles
- Improved maintenance practices and launch of an aggressive PM program
- The movement of retired buses into a contingency fleet
- The sale of buses to reduce the overall number of vehicles in the fleet to meet reduced transit service levels
- The replacement of coaches in smaller groups, allowing for reduced decommissioning batches
- Focused effort on and closer supervision of the management of small sub-fleet spares and division-to-division resource sharing
- Implementation of annual bus purchases through a 10-year contract with a single supplier that incorporates minimal specification changes from year to year, which also reduces training requirements and spare parts issues
- Decline or deferral of some special requests to a better time (when more spare buses are available); allocation of different spare ratios to different fleet types at each depot; revision of spare factors for each depot quarterly so that each depot is assigned the appropriate number of buses
- Working to establish CNG as a reliable alternative fuel choice
- Dedication to long-term asset management strategy.

Suggested Changes in Practice and Policy

When asked whether respondents believe that a 20% spare ratio for their fleet is realistic for their agency, 14 of the 38 (37%) surveyed agencies responded "Yes," whereas 24 of the 38 (63%) answered "No."

Following is a sample of respondent comments:

- Each service type has its own unique operating characteristics, maintenance demands, and, in many cases, specialized vehicle and accessory requirements. To fully meet the needs of the range of transit service types offered, the spare ratio must be sufficient within the sub-fleet(s) of vehicles that support each service type. All buses in the entire fleet are not necessarily interchangeable in their ability to support all service types.

- Without sufficient bus replacement funding, [the agency] must operate older, less reliable buses longer.
- With added vehicle support systems such as security, vehicle location systems, radio system, passenger counting systems, fare collection systems, etc., requiring more time and routine service, it is difficult to maintain and operate within the 20% spare ratio.
- It is challenging to achieve maintenance requirements with running a (rubber-tired, overhead catenary) trolley system. If the system goes down or must be taken down for construction, a 20% spare ratio will not be sufficient.
- Aged facilities are not as accessible for our growing articulated fleets.
- Smaller and underfunded systems cannot get by with a 20% spare ratio.
- With a small fleet, 20% is a workable spare ratio. The 20% spare ratio is currently viewed as being too large—a minimum spare ratio is best with which to cost-effectively operate the fleet.

The final survey question asked respondents what changes in practice, policy, or additional resource(s) would best improve their agency's ability to reduce its fleet spare ratio. Following is a sample of responses:

- Any actions that result in improved vehicle performance and reliability
- Steady state funding for timely bus replacement and overhaul to enable retirement of vehicles at the end of their useful life [no longer than 12 years/500,000 miles] as opposed to keeping buses until replacement funding is found
- More employees to perform maintenance work; maintain all staffing positions, mechanics, supervisors, etc., as "filled"; more qualified mechanics to work on buses with advanced technologies
- Improved training for maintenance staff and the resources to do so
- Stabilizing reliability of alternative fueling and advanced technologies (e.g., gasoline-hybrids)
- Increased commonality in buses and bus technologies
- Implementing proactive maintenance programs to reduce life-cycle costs, improve reliability, and minimize down time because of mechanical failures
- Pursue greater uniformity in bus fleet; maximize interchangeability of buses in the fleet to allow flexibility in order to meet service demands; avoid specialty vehicles for specific routes to facilitate meeting pull-out with limited spare buses.
- Allow for spare ratios to be calculated at the sub-fleet level, defined by different vehicle configurations or applications; allow for spare ratio fluctuations owing to changes in service delivery quantities and requirements during useful life of vehicles in fleet; allow for spare ratio realignment through vehicle replacement plans and allow flexibility for spare ratio deviations; exclude training vehicles from calculation of spare ratio.
- Improved workforce productivity and work planning practices; improved maintenance diagnostics; implementation of standard repair times and annual employee expectations, etc.; changes in the Collective Bargaining Agreement (CBA) that would provide for part-time maintenance staff or swing shifts
- Changes to improve and expand maintenance facility capacity, staffing levels, overtime, comp time, internal job functions versus external, staff productivity, inventory levels, inventory cycle counts, vehicle in-service time, vehicle technical complexities, cleaning cycles, PM cycles, and planned versus unplanned maintenance, etc.
- Minimizing need for continuous practice of having a contingency fleet
- Continuation of the dialogue between APTA and FTA concerning changes to FTA's 20% Spare Ratio Guideline would be a positive step.

CHAPTER FOUR

CASE EXAMPLES

In addition to being asked to participate in the survey, four agencies were selected as case examples to provide more in-depth explanation of an agency's particular experience, practices, and context:

- Chicago Transit Authority (CTA), Chicago, Illinois
- Denver Regional Transit District (RTD), Denver, Colorado
- Santa Clara Valley Transportation Authority (VTA), San Jose, California
- Winnipeg Transit (WT), City of Winnipeg, Manitoba, Canada.

The case examples were selected based on diversity of fleet size, geographic location, operating environment, and agency strategies and approaches to dealing with fleet management and spare bus challenges.

CHICAGO TRANSIT AUTHORITY

CTA is a multi-modal, rail and bus transit system serving the city of Chicago and suburban communities. In 2012, CTA had a fleet of 1,792 directly operated buses and a spare ratio of 14%. As shown in Table 21, CTA's spare ratio has ranged between 14% and 20% over the past five years.

Following is a discussion of CTA's key issues related to spare bus needs and related fleet management. Information was supplemented by the authors' interview with J. Ward, March 7, 2013.

Fleet Mix

CTA's current fleet of approximately 1,800 revenue vehicles is composed of 40-ft and 30-ft standard buses, and 60-ft articulated buses ("artics"). The fleet is predominantly diesel powered, with a smaller subset, approximately 15%, of hybrid-electric (diesel) coaches. CTA is currently expecting a new order of 100 artics, 30 hybrid and 70 conventional; but with this order, it will not be retiring any buses. This is to supplement the fleet because of upcoming extensive heavy-rail repairs. These vehicles will temporarily run as shuttle buses, in place of the out-of-service rail segment. Once the new buses arrive, CTA will have 308 artics. CTA also has 1,529 40-ft buses, of which 1,509 are conventional and 20 hybrid: 400 are older buses from 2001, while most of the others were acquired between 2006 and 2009.

In terms of on-board technology, CTA buses have an AVM (automatic vehicle monitoring) system that provides remote diagnostics and notifies maintenance staff of defects which can be addressed before they result in a major failure or service interruption. They will soon have a real-time locator system (RTLS); and eventually CTA will synch AVM and RTLS to streamline fleet pull-out. Mechanics and management can view AVM-logged defects either by standard or customized reports categorized by severity to diagnose bus problems.

Special Service Requirements

CTA does not currently operate any specially branded BRT buses, though BRT routes are in the planning stages. CTA does operate the Jeffery Jump circulator service with 60-ft buses branded with a special wrap. Thirty buses are branded for Jeffery Jump, and 25 buses are in service. CTA will use a standard bus for the Jeffery Jump service if needed, but cannot use the branded buses for other routes. Otherwise, CTA buses are fairly interchangeable, aside from capacity.

Service and Ridership Issues

Ridership has increased, but not to the point where it affects spares. CTA is trying to reduce bus crowding by adding additional runs. Buses are sent out as needed to reduce crowding and to improve the customer experience, particularly during peak ridership.

Operating Environment Issues

Although the topography in Chicago is not particularly challenging, the city does experience severe weather at both

TABLE 21
CTA TOTAL FLEET, PEAK FLEET, AND SPARE RATIOS OVER THE LAST 5 YEARS

Year	Total Vehicles Available for Maximum Service	Total Vehicles Operated in Maximum Service	Spare Ratio
2012	1,792	1,578	14%
2011	1,781	1,527	17%
2010	1,781	1,527	17%
2009	2,053	1,707	20%
2008	2,132	1,843	16%

Source: Chicago Transit Authority.

extremes; 2012 was a particularly difficult winter for CTA. The past few winters have been unusually wet, taxing vehicle air dry (dehumidifier) systems. In the summer, the weather is typically hot and humid. The need for spare buses is fairly level year-round. There are a few CTA garages with outdoor bus storage, which has led to such bus performance issues as greater failure of emission control systems; this results because of the increased engine idle time needed to warm up the vehicles. CTA is trying to address this issue by equipping some buses with plug-in battery chargers that can power the engine coolant heater. The buses that were retired in 2006 used "straight weight oil" 40W engine oil; CTA buses now are equipped with four-stroke engines that utilize 15W-40 motor oil, which has improved engine cranking ability under colder conditions. Street conditions within CTA's service area differ significantly between residential and industrial areas, which can have an effect on the amount of suspension repairs required. This can create more unscheduled work, but has not significantly reduced spare buses as a result of PM suspension work.

Maintenance Issues

CTA has seven garages, all of which do light maintenance. Each property can house between 250 and 300 buses. Light maintenance consists of troubleshooting and replacement of components (except engines). Most mileage-based PM is done at the garages. Brakes, major electric, major body, and engine overhaul work goes to CTA's major maintenance South Shop. Buses usually housed at North Side garages must travel a longer distance than South Side vehicles to get to/from the heavy maintenance facility. This longer transfer means buses and staff is effectively out of service for longer periods; however, it does not significantly impact available spare buses. It's a one-for-one swap, so the impact to bus availability in minimal.

Two of the seven garages cannot house a 60-ft artic because the buses have difficulty navigating through pinch points within the facility. This does affect the spare bus ratio in terms of passenger capacity; for every 60-footer that cannot be pulled out, 1.5 40-ft buses are needed, which also eats into spare ratios.

The main South Shop does not have sufficient space to hoist 60-ft buses, which can cause a backlog on heavy maintenance work. A new type of lift is currently being installed to replace failed in-ground hoists and provide more efficient operation than the back-up portable hoists. This does affect spare bus needs, because without sufficient "hoist positions," there is a substantial lead time to get buses in and out of the shops. CTA is upgrading from portable hoists to new in-ground hoists in the existing buildings. CTA also plans to install additional 60-ft lifts at the other garage; however, in the long-term, CTA will need to expand buildings to allow for more 60-ft bus capacity.

Adequacy of Fleet Replacement/Rehabilitation Program

CTA's fleet replacement and rehab program is currently adequate. But historically, CTA has been inconsistent in the phasing of its fleet replacement decisions. The goal now is to have an on-going bus replacement program. This will prevent recurrence of past problems when large elements of the fleet were acquired at the same time, resulting in much of the mileage-driven PM coming due within a relatively small time-window, and making it harder to manage maintenance staffing. CTA now has a continual bus replacement program that is spaced out more evenly. (The 2010 budget cuts had significantly impacted CTA's fleet rehabilitation program; however, CTA has now secured capital funding for mid-life overhaul program.)

Spare Ratio Sufficiency

CTA's current spare bus ratio is 16.8%. The spare ratio increases with each new bus arrival, but new demands will likely reduce it again. CTA is not satisfied that it has reached an efficient spare bus count: It is manageable, but not optimal. The spare bus ratio varies from garage to garage, and demand is lopsided to the peaks (more in morning, more in evening). The lower the spare ratio, the more maintenance that may need to be deferred.

Greatest Challenges

The two greatest challenges facing CTA with regard to maintaining a low spare ratio are:

- Outdated facilities. There is a limited footprint to park buses and a limited number of lifts to maintain them. In the short-term CTA will be expanding facilities by acquiring adjacent property. In the long-term, CTA will add new facilities. An agency cannot always rebuild where an existing garage is located, because the property may not be suitable and there is often community opposition. (In 2010, a fiscal crisis forced the retirement of 255 buses, a garage closure, and reduced peak vehicle requirement by 196.)

- Attracting talented labor (mechanics and management). Ideally, a competent mechanic can move up, but with union contracts, the gap between the mechanic and the manager salaries has been reduced significantly. There is not much incentive for a mechanic to "step up off the floor." CTA has had to increase its reliance on outside candidates to supplement the management pool; however, there are not a lot of people with both transit and technical experience. Although CTA provides additional technical refresher training for mechanics, management is primarily refresher-trained with a focus on leadership skills, not technical skills. The city of Chicago is considering training managers in technical skills also. A pool of qualified managers trained on-the-job would be a benefit.

Agency Practices in Managing Spare Ratio

Following are some of the practices and strategies that CTA employs to better manage its spare ratio:

- Keeping a fairly homogenous fleet
- Upgrading facilities by adding more spaces for artics
- Spreading out the bus replacement cycle, replacing 300 buses every two years
- Using mock-ups for training (which has a big impact on spares). Maintenance instructors try to maximize the use of bus mock-ups rather than taking a coach out of service, but occasionally, a real bus is needed, which does affect spare bus ratio. CTA utilizes some obsolete, retired buses as mock-ups, but their value as a training aid is severely limited.
- Base period availability of buses for driver training. Chicago had a huge budget crisis in 2010, and CTA had to reduce staff, but is slowly re-hiring drivers. Limited spare bus availability impacts the operator training needs. As a result, the training department is focusing on scheduling on-street driver training periods during the base period between the a.m. and p.m. peaks.

In addition, CTA is currently looking into a different inspection process that will improve the spare bus situation. CTA is considering a "one-stop shop" where a bus would be inspected and repaired immediately, thus eliminating wait time and reducing the number of buses being tied up.

Lessons Learned

When CTA reduced its fleet in 2010, it wanted to minimize the impact felt by customers by maintaining as much service as possible with the reduction in buses. The planning department maximized "interlining" (linking routes together), running buses directly from line to line. Initially, some routes were identified where a 60-ft bus interlined with a 40-ft route. This taxed the 40-ft bus spare fleet because 60-ft buses could not be operated on those routes. This was a temporary glitch and corrections were made that reduced the number of peak vehicles needed.

In addition, CTA is evaluating the need to increase its spare ratio to the FTA allowed 20%, which it believes would provide the optimal level to meet both service and maintenance requirements. When running too lean a spare ratio, CTA has found that the potential exists for any "hiccup" to affect service, costing both money and customer goodwill. Although CTA is currently able to cover service and PM with less than a 20% ratio, it believes that 20% would be ideal.

DENVER REGIONAL TRANSPORTATION DISTRICT

RTD is a regional, multi-modal, light rail and bus transit system serving greater Denver and surrounding communities. In 2012, the RTD had a fleet of 1,003 buses and a spare bus ratio of 28% for its directly operated fleet, and 26% for its contract-operated buses. As shown in Tables 22 and 23, over the past five years the spare bus ratio for RTD's directly operated fleet has ranged between 28% and 32%; for its contract-operated fleet, the spare ratio has ranged between 20% and 26%.

TABLE 22
RTD TOTAL FLEET, PEAK FLEET, AND SPARE RATIOS OVER THE LAST 5 YEARS—DIRECTLY OPERATED

Year	Total Vehicles Available for Maximum Service	Total Vehicles Operated in Maximum Service	Spare Ratio
2012	573	442	28%
2011	574	450	26%
2010	598	450	32%
2009	625	468	32%
2008	642	493	29%

Source: Denver Regional Transportation District.

TABLE 23
RTD TOTAL FLEET, PEAK FLEET, AND SPARE RATIOS OVER THE LAST 5 YEARS—CONTRACTED

Year	Total Vehicles Available for Maximum Service	Total Vehicles Operated in Maximum Service	Spare Ratio
2012	430	342	26%
2011	450	371	21%
2010	435	360	21%
2009	438	363	21%
2008	434	363	20%

Source: Denver Regional Transportation District.

Following is a discussion of RTD's key issues related to spare bus needs and related fleet management. Information was supplemented by the authors' interview with D. Shaklee, March 8, 2013.

Fleet Mix

RTD's bus fleet mix consists of 30-ft (standard floor and low floor) buses, 40-ft (standard and low floor) buses, 60-ft articulated buses, OTR coaches, specialty (45-ft) downtown mall buses, and small cutaways. The private contractors run the 30- and 40-ft coaches and the cutaways. The on-board systems are the same in all buses (e.g., automatic passenger counters, radios, fareboxes, etc.). The fuel systems represented in the fleet include hybrid-electric CNG buses, hybrid-electric diesel, and clean diesel.

Special Service Requirements

The RTD serves a very large, eight-county area covering mountains, foothills, and flatlands; and provides local service, express service, regional service, and mall buses that run along the 16th Street Mall in downtown Denver. The contract fleet provides local transit service and a few express routes (with standard 40-ft buses). The RTD also oversees six branded bus routes in Boulder: the Hop, the Skip, the Jump, the Dash, the Bound, and the Stampede. These routes are serviced by 30- and 40-ft buses with unique paint schemes. The Skip runs in the Boulder area; the Stampede runs through the Colorado University (CU) campus. The private contractor runs the Hop, Jump, Bound, and Stampede, while RTD directly operates the Skip and the Dash.

If necessary, RTD will use a standard RTD bus on a branded route if a branded wrap bus goes out of service and a branded spare is not available. RTD directly operates three-axle, OTR "highway-style" coaches on routes that travel into the mountains to a ski lodge, carrying skiers in winter and bicyclists in the summer. These OTR-buses also provide service to the Denver International Airport. RTD prefers not to run standard transit buses (40- or 60-ft artics) on these routes, but will do so if necessary. RTD very rarely sends artics up into the mountains, because of their operational limitations on snow and ice.

Service and Ridership Issues

In January 2012, RTD had a reduction in service of about 10% because of the slowed economy. This resulted in an increase in the spare bus ratio between 2011 and 2012. Some buses were retired. Other vehicles were placed in a contingency fleet, but were returned to service owing to installation of a new smart card and CAD/AVL radio system. Even with the reduced level of service, ridership was only down by 0.4%.

RTD directly operates a significant number of special services, including NFL Broncos game shuttles, senior shopper specials, emergency light rail back-up (bus bridges), and increased CU-to-airport service. Three times a year—Thanksgiving, Christmas, and spring break—there is a mass exodus of CU students who need transportation to the airport. During each of these periods, 100 buses are added over the course of a week. On any given day, up to 17 additional buses may be needed. Private contractors do not operate any of these special services, so they all put significant pressure on the RTD spare bus fleet.

Operating Environment Issues

RTD operates buses under both cold and hot weather extremes, in addition to the significant challenges of high altitude—5,280 feet in Denver. Buses at that altitude have less power than those operated at sea level because of the lower concentration of oxygen in the air and the resulting strain on engine fuel combustion.

In the winter, there are prolonged periods of below-zero temperatures, the city streets are rutted, and the snow is piled up. RTD buses also deal with rough pavement because the freezing and thawing creates numerous potholes in the winter. Emission controls systems on buses do not operate as efficiently in the cold weather, so the exhaust filters clog up faster, causing warning lights to activate sooner; all these factors affect RTD's available spare bus ratio. The cold temperatures affect the private contractors even more, because they have to park their buses outdoors (while RTD garages buses), so their buses idle more and air filters clog sooner.

RTD buses also travel as high as 8,000 feet into the mountains, where lower oxygen levels affect operations. Combined with summer temperatures reaching into the 100s (°F), the elevation often causes overheating: RTD bus engines are required to have cooling systems pressurized at 14 pounds, twice the standard seven-pound pressure, in order to raise the boiling point. In winter, RTD faces challenges with non-starting buses and failing in-bus heating systems.

All RTD buses have transmission retarders that increases brake life but typically reduce transmission life by an estimated 20% to 25% because of the heat generated by the retarder, especially on steep grades coming out of the mountains. This also draws on spare bus fleet.

Maintenance Issues

For its directly operated bus fleet, RTD uses three bus storage facilities—Boulder, Platte, and East Metro—and one district shop. Basic maintenance is performed at the storage facilities, while major maintenance work is the responsibility of the district shop. The private contractors have a total of four facilities (one has three contracts and three facilities, the other has one contract and one facility), but they do not have repair or reconstruction capabilities; instead, they purchase rebuilt parts and sublet body work.

As noted, RTD parks its directly operated fleet indoors, leaving the contactors to park their buses outdoors. The private contractors cannot exceed 125 buses at any of the four locations. RTD-operated buses are allocated among the three bus storage facilities: 280 in Platte, 200 in East Metro, and 113 in Boulder. RTD has two contractors.

Both the RTD facilities and the contractors' facilities run the same maintenance programs; the contractors often assist each other. The transferring of buses is controlled exclusively by RTD, which will assist the contractors when necessary to supply service. The only time a bus deadheads for maintenance work is when it needs to come to the district shop for major repairs. The three RTD facilities can all do minor PM and repairs necessary for everyday pull-out, and so can contractor facilities. When the Platte division was built in 1976, it was built for 250 40-ft buses. Now it supports 45- and 60-ft buses. The East Metro facility was built in 1980 to house both 60-ft buses as well as 40-ft transit buses. Boulder was built in 1976, and does not support artics. These constraints affect RTD's spare needs and spare ratio because it takes longer to hoist buses and repair them.

RTD has a maintenance training staff of five full-time instructors. There are nine certification zones that are linked to mechanic pay raises. RTD has a major challenge in hiring and retaining skilled mechanics. Toward addressing that challenge, RTD has created a mechanic helper program. Program candidates take dexterity and aptitude tests, and then enter a modified apprentice program for about four months, becoming proficient in how to inspect and perform minor repairs. Over the next two years, they take other classes and prepare to take the mechanics' entrance test. However, this program still does not provide enough mechanics. RTD also recruits from Wyoming Tech and Lincoln Tech, which have heavy-duty vehicle maintenance programs. The lack of qualified mechanics affects the overtime budget, but not so much the spare bus ratio. Driver training requires seven to 10 buses a day. Buses are made available for driver training only in off-peak periods; midday training buses must return for PM pull-outs.

Adequacy of Bus Replacement and Rehabilitation Program

Currently, the RTD-operated fleet is relatively old, with an average age of 10 years. The average age of the contract buses is six years. Fifty-four (54) OTR coaches have started to arrive, which will help significantly.

Orders for newer buses were split with private contractors. RTD is feeling the pain of the old fleet in the form of higher levels of maintenance and reduced reliability. In 2000, the RTD purchased more than 700 buses; these will be replaced over the next three years, meaning that some will be 17 years old before being retired.

Spare Ratio Sufficiency

In 2012, the directly operated fleet spare bus ratio was 28%. The FTA allows RTD not to factor in the special buses that operate on the 16th Street Mall in downtown Denver. Currently there are 38 mall buses; RTD operates 23 at peak. The 2012 spare ratio for the contractor-operated fleet is 26%. RTD is replacing all the CAD/AVL radios along with installing a smart card system, so the contractors' spare ratio is higher while the work is being done. The oldest contractor-operated buses are from the year 2000, about 25% of the fleet, while the newest buses were acquired in 2008; RTD wants the age ration to be more balanced. As the contractor-operated fleet average age goes up, the allowable spare bus ratio will need to increase.

RTD staff believes the agency's current spare ratio to be insufficient. In January 2013, there was an increase in service, a return to the levels before the 2012 service reductions. This resulted in the reintroduction of several buses that had been spares into peak service. The resulting current spare ratio for 40-ft buses is below 20%. The combined RTD-operated and contractor-operated fleets now has a spare ratio of 18.9%. RTD would like to see it at about 25% overall (higher for RTD special services); for the contract-operated fleet, 25% is thought to be sufficient given the age of the younger fleet. Regarding the sub-fleets, a higher spare ratio is needed for articulated buses, and a lower spare ratio for 30- and 40- footers. The opening of a new light rail line enabled a reduction in bus service, so some artics and OTR coaches may be available for spares.

Greatest Challenges

The greatest challenges facing RTD with regard to maintaining a low spare ratio are:

- The intensive and intermittent nature of some of the special service requirements (e.g., university service to the airport); and the unique bus types that are needed for certain services (e.g., the branded shuttles).
- The average age of the fleet and the large number of older buses on the same life cycle. The agency's financial challenges have resulted in its significantly extending the service life of its buses, now past 12 years and/or 500,000 miles on about 500 vehicles.
- Wide variations in temperatures and altitude, and the attendant toll these take on bus performance and reliability.

Agency Practices and Strategies

Following are some of the practices and strategies that RTD employs to better manage its spare ratio:

- The agency tries to schedule any activity (PM, PM repairs) on weekends, when a bus is not required to be in service.
- When a bus comes in with a driver defect, it is moved to the first of the line; 40-ft buses are the most needed in the fleet.
- RTD is striving to spread out bus purchases to the point where it is buying 150 buses every year so as to stagger the replacement cycle.
- RTD does a preemptive large component change-out during the off-shift at intervals to avoid in-service failure.
- The agency is transitioning to a higher pressure cooling system (14-lb vs. seven-lb).
- RTD is attempting to maintain buses at a higher level; for example, maintaining air system driers year-round to make sure the air systems stay dry for the winter, thus reducing air system freeze ups; maintaining auxiliary fuel heaters year-round to make sure heating system work; scheduling PM at 6,000-mile intervals; focusing on springtime radiator clean-out to prevent overheating during the summer; monitoring the air cleaners nightly, to make sure the engines can breathe (air filters, etc.); and conducting above-and-beyond daily servicing requirements to anticipate wear because of extreme temperatures.

Lessons Learned

Purchasing new buses, reducing special services during the day, and having driver trainees use buses at night or weekends will all help manage the spare bus fleet. Inactive contingency buses are maintained regularly and to the same level as active fleet; many are used for the CU exodus and for driver training. RTD places only the best of the old coaches into the contingency fleet.

SANTA CLARA VALLEY TRANSPORTATION AUTHORITY

VTA is a regional, multi-modal light rail and bus transit system serving greater San Jose and surrounding communities. In 2012, VTA had a fleet of 426 directly operated buses and a spare bus ratio of 23%. As shown in Table 24, VTA's spare bus ratio has ranged between 23% and 30% over the past five years.

Following is a discussion of VTA's key issues related to spare bus needs and related fleet management. Information was supplemented by the authors' interview with H. Samuels and J. Petty, March 7, 2013.

Fleet Mix

VTA's bus fleet mix consists of standard 35- and 40-ft buses; 60-ft articulated buses; and less-than-30-ft "cutaway" buses. Most VTA buses are diesel; however, over the past few years the agency has acquired hybrid-electric (diesel) powered vehicles. VTA's cutaway buses are currently gasoline-powered;

TABLE 24
VTA TOTAL FLEET, PEAK FLEET, AND SPARE RATIOS OVER THE LAST 5 YEARS

Year	Total Vehicles Operated in Maximum Service	Total Vehicles Available for Maximum Service	Spare Ratio, %
2012	426	345	23
2011	431	332	30
2010	412	350	18
2009	424	336	26
2008	456	349	30

Source: Santa Clara Valley Transportation Authority.

this small vehicle sub-fleet will soon be replaced with hybrid-diesel-powered vehicles. VTA acquired and tested hydrogen buses in the early 2000s, but concluded that they were very expensive to operate and difficult to maintain; these buses are no longer in use.

VTA has worked hard to comply with California Air Resources Board (CARB) rules. A few years back, CARB pushed transit systems to reduce emissions. VTA continued to lean on diesel, but explored cleaner operations using low-sulfur diesel and hybrid technologies. The fleet is currently very green. The on-board technology systems have been fairly reliable on VTA buses.

Special Service Requirements

In addition to regular local bus service, VTA operates BRT service using 40- and 60-ft branded buses that have a traffic signal priority mechanism on board. In addition, VTA operates Express buses with a single front door and high back seat coaches; and Airport Flyers to the light-rail line and airport parking lots that have luggage racks and passenger counters, but do not have fareboxes. VTA also operates Community Buses, a downtown shuttle service, and feeder service in areas with lesser demand where large, standard buses are not needed.

The vehicles assigned to the BRT, Express, and airport routes are only used only for those particular services, which significantly limits the agency's ability to transfer vehicles to address other needs. For example, VTA will soon be purchasing 60-foot hybrid artics for its BRT service; once BRT-branded, these buses cannot be used on any non-BRT high-demand route, which challenges the spare bus ratio. Community buses are also specifically branded by body style and paint scheme; and their smaller capacity and lift type restrict flexibility in their assignment.

Service and Ridership

VTA's ridership and service levels have fluctuated in recent years. An efficiency study resulted in a reduction in service and fleet size from 2008 to 2009, and financial pressures led to further reduction in service in 2011. However, services were restored in 2012 as ridership began to increase, and VTA expects continued, though small, passenger growth. The agency is constantly trying to attract more customers and improve efficiency.

Operating Environment Issues

Santa Clara's nice weather and small number of steep hills do not make for a taxing operating environment, but there are a few issues affecting spare bus needs that are worth mentioning.

The Airport Flyer service route is very flat. Its hybrid buses operate at low speeds and make frequent stops. This does not provide an opportunity for the clean air exhaust after-treatment to get to the operating temperatures needed to make the exhaust system work properly and burn off the particulates. In addition, bus radiators often get clogged from the significant construction dust in the Santa Clara Valley, necessitating additional service to prevent overheating.

There has also been a group of coaches that has experienced frame cracking, although the cause has not yet been determined; it could be pavement quality, potholes, or something completely unrelated. Buses with cracked frames must be withheld from service; and the entire frame must be exposed for welding; so repair can take several months, drawing on the spare bus fleet and affecting the spare ratio.

If the defect is minor, the monitored bus can remain in service until it can be fixed. Fortunately, this flaw is affecting the largest sub-fleet—standard 40-ft buses—which has more spares to plug in when needed. The small cutaway buses have also experienced suspension cracking as a result of road conditions. VTA has upgraded to higher quality parts, but that makes the ride less smooth for passengers.

Maintenance Issues

VTA has three operations and maintenance divisions and one overhaul/repair facility, located at three different edges of the San Jose area. The shops offer some different services—paint and body, upholstery, etc.—and each has its own parts storeroom. There is not much shuttling of buses between divisions. Most vehicles start/end their runs near one of the three maintenance divisions to minimize deadheading. PM inspections, fueling, detailing, and other day-to-day maintenance are performed at all three divisions. Facility issues have not impacted spare bus needs at VTA.

Adequacy of Bus Replacement and Rehabilitation Program

A few years ago, VTA had a large group of vehicles that had been in the fleet longer than the typical lifecycle of a coach, which meant that all the vehicles in this group were scheduled to be replaced at the same time. VTA targets replacement of heavy-duty buses every 13 to 15 years, and medium- to light-duty vehicles every five to seven years. Rehab is generally performed every seven years, though the actual rehab approach is customized to each coach type. The hybrid buses are a relatively new addition to VTA's fleet, so the agency does not have a long-time estimate of what the hybrid maintenance requirements will be over the long haul. In an effort to learn more about the impact of the duty cycle on hybrid life, VTA is subjecting some vehicles to accelerated work and wear.

Having an overhaul and rebuild facility, VTA is able to do much of its major maintenance work in-house, with the result that staff mechanics are familiar with the vehicles in the fleet. This benefits substantially in maintaining the optimal level of spare vehicles; the agency believes that it would otherwise need more spare vehicles. VTA also uses decommissioned buses for parts, trying to keep one bus type per series if possible.

Spare Ratio Sufficiency

FTA has reprimanded VTA for exceeding the 20% spare ratio guidelines, although VTA tries to adhere to the limit as effectively as it can. As of 2013, a 23% ratio appears to be manageable. In some sub-fleets, VTA has more spare buses than needed, but fewer in others. VTA believes that having a 20% spare ratio for each usage type would be better than a 23% ratio overall, although it does not intend to expand the spare bus fleet at this time. When PM inspections are scheduled, it can be difficult to maintain the balance without jeopardizing bus pullouts.

VTA tries to cluster similar buses (i.e., all airport buses) at one yard to ease scheduling challenges. It also tries not to deploy specialty sub-fleets on other routes (i.e., Express buses on the branded airport loop), because that has created confusion among riders. Ridership and service level fluctuations also affect the spare ratio. VTA tries not to overreact to short-term swings in ridership or service by selling off buses or acquiring new buses; so under those varying circumstances, the spare ratio may be larger or smaller than desired.

Greatest Challenges

Some of the greatest challenges facing VTA with regard to maintaining a low spare ratio are:

- Lack of interoperability among sub-fleets vehicles
- Having sufficient numbers of buses available for operator training. With a higher percentage of mechanics and drivers retiring, there is a need for more training classes for maintenance and operations staff, which requires the availability of all types of coaches in the fleet. However, making more buses available for training affects spare bus availability and places pressure on the spare ratio.
- Maintaining sufficient maintenance staffing levels
- Responding to special service needs, such as providing service for the San Francisco 49ers stadium, BART expansion, and BRT build-out.

Agency Practices and Strategies

Following are some of the practices and strategies that VTA employs to better manage its spare ratio:

- Creating and maintaining a culture of discipline and teamwork at VTA across all departments (maintenance, operations, engineering, planning, etc.). The staff at VTA works collaboratively to manage the fleet within the given parameters (funding, staffing levels, etc.) while still maximizing condition of the vehicles and transit services provided to the public.
- Fostering proactive communication among all maintenance and operations parties involved, which is key to actively managing the fleet. It is important that all affected staff understand issues, tradeoffs, and fleet requirements in order to make the right decisions. This process needs to be transparent, where nothing goes unnoticed and any potential hiccup can be anticipated. One of the agency's mantras is, "Make sure the shop has the tools . . . to make the best decision at the worst possible time."
- Engaging management. VTA has learned to keep tabs on pull-out decisions. If the agency is not careful, the inactive fleet, BRT, Express or Airport Flyer vehicles might be used inappropriately. It is important to consistently reinforce, from the top down, what the fleet requirements are for each route, and that deviation from the rules or from the plan does matter. This ensures that the right buses are on the right routes at the right times. If buses are assigned to the wrong run at the wrong time, it must be addressed immediately; otherwise, frequency of such errors will increase.
- Using the contingency fleet and base period to support training needs. VTA uses the inactive contingency fleet to get new drivers oriented and trained for as long as possible. It also strives to use active fleet coaches during the base period (between the peak demand periods) for training purposes, limiting the impact on the spare bus fleet.
- Avoiding retiring buses in large groups. Breaking new bus purchases and old bus retirements into smaller groups is more efficient in terms of staff time needed for the commissioning and decommissioning.

In addition, VTA has a "Joint Workforce Investment" (JWI) initiative that works with crews, foremen, and union leadership to move forward with mutually beneficial practices. JWI members are developing new informational handbooks, resource guides, forms, and other materials to help foremen and line workers make better decisions, do their jobs more effectively, and cross-train and maintain active communication at all times. This helps maintain an optimal bus spare ratio at VTA.

Lessons Learned

With regard to better managing its spare bus ratio, VTA staff believes that it would be very helpful to have flexibility that recognizes sub-fleets and allows them to be managed independently. It is also critical to consider all the implications that the wave of baby boomer retirements may have on spare bus fleet needs and resulting spare ratios (e.g., training needs, etc.).

VTA believes that a strong maintenance training program has a very high ROI in terms of cost-effectively managing the fleet and the spare bus ratio. VTA often looks to the training department as a critical resource in dealing with maintenance problems and issues. And with rapidly changing technology, the training program is key to ensuring that the maintenance staff has the capabilities and skills to support the bus fleet. VTA used to have a trainer at each yard, but funding cutbacks eliminated them. Now there is a single central training center, but the program is not likely to be reduced further. The training program has clearly helped VTA maintain a lean spare bus ratio.

CITY OF WINNIPEG TRANSIT DEPARTMENT, WINNIPEG TRANSIT

Winnipeg Transit

WT is a regional, bus-only transit system serving greater Winnipeg, Manitoba, and surrounding communities. In 2012, WT had a fleet of 565 directly operated buses and a spare bus ratio of 12%. As shown in Table 25, WT's spare bus ratio has ranged between 12% and 15% over the past five years.

Following is a discussion of WT's key issues related to spare bus needs and related fleet management. Information was supplemented by the authors' interview with T. Dreolini, March 8, 2013.

Fleet Mix

WT has a current fleet of 563 buses. The fleet is fairly homogenous, consisting primarily of 40-ft standard buses; 35 vehicles are 30-footers. WT is in the process of getting new (2012) buses, retiring old coaches as new ones are added. WT's fleet is all diesel-powered, with basic technology, including GPS, next stop announcements, video surveillance, etc. When the funds are available, WT adds technological upgrades, such as electronic fare boxes, the biggest technological change in the pipeline. WT has only 50 high-floor buses left; the remainder of the fleet is low-floor.

Special Service Requirements

WT's service design and its homogenous bus fleet provides for significant interchangeability of buses throughout the system. The 40-ft coaches can operate on most routes. The 30-footers are typically placed on routes with lower ridership, such as suburban routes and the downtown shuttle service called the Downtown Spirit. The Downtown Spirit service runs on three routes. Sponsors help promote the service, so regular Downtown Spirit buses have a branded wrap and sponsor identification. Although WT prefers to use the specially wrapped buses on Downtown Spirit routes, a standard non-wrapped 40-ft bus can be deployed on the Downtown Spirit route if necessary.

Conversely, WT has the flexibility to use wrapped buses on other (non-downtown) routes. WT's BRT service also has 35 specially wrapped buses that run along the corridor and then service other parts of the city. When needed, WT places BRT-wrapped buses on other routes. This does not appear to cause confusion, and WT would prefer using a wrapped bus versus missing service with no bus at all. According to WT, riders are accustomed to seeing wrapped buses all over the city; as long as the headsign shows the route they want, customers will board. Having buses that can run anywhere on the system is a major factor in maintaining a lean spare bus ratio.

Service and Ridership Issues

WT ridership has been steady for the past 10 years, with growth of 2%–4% annually and peak demands increasing dramatically. WT has always maintained a fairly lean spare bus ratio, so as additional peak service has been implemented, it has had to increase the number of spare buses to maintain the ratio by keeping older viable buses in the fleet. When it comes time for the annual replacement of 30 buses, the agency will only retire 20. Winter has the highest ridership of the year, partly because universities

TABLE 25
WT TOTAL FLEET, PEAK FLEET, AND SPARE RATIOS OVER THE LAST 5 YEARS

Year	Total Vehicles Available for Maximum Service	Total Vehicles Operated in Maximum Service	Spare Ratio
2012	565	504	12%
2011	550	485	13%
2010	545	480	14%
2009	545	476	15%
2008	535	470	14%

Source: City of Winnipeg Transit Department.

and schools are in session, and also because weather conditions can be so severe that persons who would otherwise drive will ride the bus to avoid accidents, gridlock, etc. Many people also avoid driving in the winter because if they must park outdoors, their cars may not start at the end of the work day.

Operating Environment Issues

Winters are extremely cold in Winnipeg, with a fair amount of snow. Winter temperatures regularly dip to 25° below zero Celsius (–13° Fahrenheit), to 30°C below (–22°F) a few times a winter, and, rarely, reach 40°C below (–40°F). Snow is frequent, with a true blizzard passing through every few years. During winter months, on-street traction control is by salt, sand, or a combination depending on the outdoor temperature. Buses are parked indoors; when snow and salt accumulations on the undersides of buses melt, it creates an extremely corrosive environment for mild steel structural tubing. In response, WT must do a complete structural refurbishment at approximately the mid-life of the bus (after 10–12 years of service) to ensure the structural integrity of the bus is not compromised. This structural rehab is essential to achieving the targeted 18-year bus life span and maintaining the low spare ratio.

Summers, on the other hand, can be quite warm, though not extremely hot. Temperatures are routinely around 25°C (77°F), but can rise to above 30°C (86°F) in July and August.

In 2007, after years of consideration, WT introduced air conditioning in buses to enhance customer comfort during summer months. However, if a bus's air conditioning fails, it can continue in service because windows on the coach can be opened. The entire fleet is not yet air-conditioned, so encountering a bus without AC is not unusual for customers.

Maintenance Issues

WT has two garages. The main facility, Fort Rouge, houses 430 buses and handles the major overhauls and higher-level inspections (and resulting repairs), in addition to providing standard daily support. North Garage is a satellite facility housing 135 buses that handles daily servicing, routine PM inspections, and basic repairs. North Garage does not perform any heavy overhaul activities. Seven to 10 buses a day start at one garage and end at the other. Fleets are not dedicated or assigned to either garage; WT tries to evenly distribute old and new vehicles, with air-conditioning units and without.

At WT, pre-scheduled inspections are synched with route planning to ensure that each bus ends up at the right garage at the right time for inspection and repair. Inspections are scheduled several days in advance. To help manage its fleet, WT uses a highly sophisticated in-house work order/inventory/dispatch/parking database system (a maintenance management information system or MMIS) developed in the 1990s. This system can locate buses that are parked in the garages; when they are scheduled to enter service; when they are scheduled to return from service; and to which garage they are returning. The system also provides information to dispatchers and maintenance supervisors on which buses are available for service at any time; which can be dispatched for the next peak dispatch period but must return following that peak for scheduled maintenance; whether buses are scheduled by another department for maintenance to allow multiple maintenance activities to occur at the same time; and whether non-critical maintenance need to be deferred as a result of a shortage of buses.

The MMIS also has a bus history to help with the diagnostic process for repairs. It enables a check to see if a part is in stock; if not, the system tracks part arrival and repairs. When parts are used, inventory is automatically updated. When levels are low, a notification is sent to buyers. This system can also search for comparable parts for older buses. These multiple features help to minimize repair time and in turn support a lower spare ratio. This is particularly important during the winter months, when the greatest number of buses is on the street and external conditions are the most challenging.

Adequacy of Bus Replacement and Rehabilitation Program

WT has had a highly focused and proactive bus replacement and rehabilitation program going back to the 1980s. As mentioned, WT targets an 18-year life span for its coaches, so it staggers bus purchases at approximately 30 buses per year. A consistent number of purchases on an annual basis helps to balance the workload from season to season. Bus specifications are kept as consistent as possible, but the agency does incorporate new features to improve performance.

As noted, WT maintenance staff monitors conditions of frames, and starts refurbishing after 10 to 12 years. The outside "skin" of the bus is peeled away and portions of the frame that are perforated or so corroded that will likely fail before the bus is retired are replaced. WT refurbishes about 30 buses per year; this process takes approximately six weeks. It is largely a structural procedure, although it also includes other key components of the bus including the floor, seat inserts, paint, etc. This refurbishment also contributes to keeping the spare bus ratio lean. This mid-life refurbishment is intentionally performed at a level that will enable the bus to last 18 to 20 years; staff does not work to extend the bus to a 30-year life. Power train repair is done independently.

Since 1988, all WT buses have been purchased from a single vendor. Although such an arrangement is highly unusual in the United States, WT currently has a long-term (10-year) contract with one bus manufacturer. It is structured so that, on an annual basis, WT can place a bus order if funding is available without having to go out for competitive bids each time.

Training and parts commonality are other advantages of having a uniform fleet. When this strategy was devised, WT had a very diverse fleet that was difficult and expensive to manage. Prior to 2004, WT typically had a one-year or three-year procurement. In the 1990s, there were many times when WT could not purchase any buses; however, in the past few years funding has been stable, so it has been able to stick with the annual purchase plan. This uniformity of fleet, parts inventory, and training contributes to WT's very lean spare ratio. (The procurement practices allowed in Canada enabled the 10-year bus purchasing contract described previously.)

Spare Ratio Sufficiency

WT has found its lean spare ratio to be sufficient to support both its service mix and maintenance program. At peak periods, there are very few to no spare buses, and sometimes buses scheduled for PM will need to be dispatched in the winter. The lean spare ratio sometimes requires that certain non-safety related defects identified in a PM inspection be deferred (all buses are checked out by WT mechanics before being placed back into service).

Greatest Challenges

Some of the greatest challenges facing WT with regard to maintaining a low spare ratio are:

- Weather-related and shorter-term issues. These include cold buses, air and heating system problems, and suspension issues such as stiffer, rougher rides. After snow or ice or freezing weather, there is a spike in accidents. For minor fender benders, buses may remain in service. As mentioned, many longer-term winter weather impacts are related to salt corrosion.
- Facility constraints. WT does not have room to fit any more buses inside, so some buses must be parked outdoors. A new parking, fueling, and cleaning facility next to Fort Rouge is coming on line. Maintenance bays are adequate right now, but WT plans to provide additional maintenance capacity in the future to meet anticipated increased ridership and buses.
- WT has not experienced financial challenges that have impacted its spare bus ratio.

Agency Practices and Strategies to Manage Spare Ratio

As previously detailed, WT has employed multiple strategies and practices that have enabled it to maintain a very low spare ratio, including:

- Fleet uniformity strategy. The homogenous fleet of predominantly 40-ft buses (and a small sub-fleet of 30-ft buses), all diesel-powered (no alternative fuel/propulsion technologies) and mostly built by a single manufacturer, has been a major factor in WT's low spare ratio.
- Extensive interoperability between regular and niche services and bus types (including special wraps and branding). Although every effort is made to match a bus type with its appropriate service, WT has the flexibility to assign just about any bus to any route as long as it has adequate capacity.
- Steady and proactive bus replacement and rehabilitation programs. As described, new buses are scheduled for procurement at a rate of approximately 30 per year, and an equal number of older buses are retired. The refurbishment program ensures that buses are available for a service life of 18 to 20 years.
- Use of service trucks for repairs in the field. WT has mechanics in service trucks driven by journeyman, assigning one truck during peak service. These service trucks generally park in a centrally located place during the service day. In the event of a bus driver's calling dispatch, the truck can schedule a meet-up with buses on-route, or go to stalled buses. In really cold weather, WT may add another service truck. This service can often prevent the need for time-consuming (and service-impacting) bus swaps. Real-time communication allows for quick adaptability for addressing issues.
- Stable and well-trained staff. WT has been able to attract and retain maintenance workers who have spent their entire career, as much as 30 years, at WT. This capability has enabled WT to efficiently manage workload to meet dispatch requirements and support the wide range of functional areas and specialty shops (body, A/C, electrical, etc.). Mechanics receive extensive training in-house. Journeyman mechanics do most work in-house, which is less expensive and allows supervisors to better balance workload, and makes mechanics familiar with the fleet. (In Canada, each province oversees the training and certification of mechanics and other technical professions in conformance with standards established nationally.)

Lessons Learned

A number of agency strategies and practices have been implemented as a result of lessons learned over the years, including:

- Not buying small numbers of unique buses. It is difficult to stock parts and provide training and specialized maintenance for so few buses.
- Not buying the first buses of a new model off the assembly line. Parts are rare, and there is not a lot of repair expertise around.
- Maintaining a strong PM program. WT subdivides fleet by teams, so that inspectors inspect the same group of buses, become familiar with them, and can fix many defects on site. WT has different levels of inspections:

"A" inspections at 4K intervals (approximately 2,500 miles); "B" inspections at 12K intervals (approximately 7,500 miles); and "C" inspections at 48K intervals (approximately 30,000 miles). "A" inspections are done at night: These monitor bus conditions to schedule repairs and address safety related checks, including brake linings, tires, etc. Most "B" and "C" inspections are performed during the day shift (7:00 a.m.–2:30 p.m.), and include oil and filter changes, etc. In "B" inspections, undercarriages and compartments are power-washed to remove salt and provide visibility to identify leaks, corrosion, abraded hoses and wires, etc. For the major "C" inspections, WT allots more time for repairs during the inspections so there is less deferral of defects.

According to WT, improvements to methods and equipment are ongoing and the level of maintenance is not being reduced as a result of the low spares ratio. The fleet is in good condition; WT indicated that at this time the lifespan of the oldest buses in the fleet could be extended.

CHAPTER FIVE

CONCLUSIONS

This chapter summarizes findings, reports promising practices, and shares suggestions for additional research. It also lists other potentially useful resources to practitioners.

There is no "one size fits all" model when it comes to determining the optimal size of a bus fleet and its attendant spare ratio. Each agency's bus fleet has unique attributes, service demands, environmental factors, and maintenance issues, some of which have adversely impacted some transit agencies' abilities to keep lean spare ratios while not significantly affecting other agencies.

FTA's policy states that "the basis for determining a reasonable spare bus ratio takes local circumstances into account," an indication of some flexibility with regard to the maximum number of spare buses allowed by FTA. The study found that FTA does grant some degree of latitude and considers local conditions when evaluating bus spares, particularly in their consideration of action plans they require of grantees that have exceeded the 20% threshold. In these action plans, grantees provide FTA with the approach they intend to take over a period of time to bring their spare ratio back to an acceptable level.

Following is a recap of some of the more pertinent findings of the survey:

- Of the 35 directly operated fleets surveyed, nearly half (17, or 49%) were within the 20% FTA spare ratio guideline, while an equal number exceeded the 20% threshold (there was one non-response). Most of the directly operated fleets, 26 of 35 (74%), had spare ratios at or below 25%.
- Comparing spare ratios by directly operated fleet size groups indicated that five of the nine very large fleets and five of eight of the mega-fleets had spare ratios at or below the FTA 20% guideline.
- Tracking agency spare ratio trends over past five years showed that 16 of the 35 (46%) directly operated agency fleets were able to reduce their spare ratio from 2008 to 2012; 13 (37%) increased their spare ratio over this period; and five (14%) stayed the same.
- When asked whether respondents believed that a 20% spare ratio for their fleet is realistic for their agency, 14 of the 38 surveyed agencies (37%) responded "Yes," whereas 24 (63%) answered "No."
- Of the 35 directly operated fleets surveyed, 24 of 35 (69%) had three or more different sub-fleets. By fleet size grouping, four of eight medium fleets and six of six large fleets had three or more different sub-fleets.
- According to the weighted scores provided by the survey respondents, two factors appear to have the greatest impact on the number of spare buses that are required to support an agency's services and maintenance requirements: the age/mileage of the fleet (with a weighted score of 112); and intensity of duty cycles (with a weighted score of 100).
- Twenty-three of 38 respondents (61%) reported their fleet vehicles had an average age between 6.0 and 8.9 years old. Only eight of 38 fleets (21%) had an average age of more than 8.9 years.
- When asked if the average age or cumulative mileage of their fleet affected their spare bus needs and fleet spare ratio, 22 of the 38 surveyed agencies (58%) indicated "Yes," whereas 16 (42%) responded "No."
- Clearly, diesel continues to be the predominant fueling and propulsion system for buses in the respondent fleets. Diesel buses are deployed by 35 of the 38 agencies responding (92%); hybrid-electric buses by 24 agencies (63%); and compressed natural gas buses by 17 (45%). Only five of the 38 responding agencies (13%) were exclusively diesel-powered.
- Of the 38 total respondents surveyed, 25 (66%) had more than eight on-board technology systems to maintain in their fleet; nine (24%) had more than 10. Only 12 of the 38 (32%) respondents had eight or fewer on-board technology systems to support.

Numerous challenges in managing bus fleets and spare ratios were identified in both the survey and case examples. Many, though not all, of these difficulties are rooted in an agency's financial challenges, which can be a determinant of spare bus requirements and a contributing factor to an agency's spare ratio. Asked whether financial challenges have impacted each agency's spare bus needs and spare ratio, 22 of the 38 survey respondents (58%) replied "Yes" and 16 (42%) responded "No." Those who identified such challenges listed reduced capital dollars for needed bus replacement; reduced maintenance staffing levels; and transit service reductions (resulting in unused vehicles) as the three major impacts.

Other critical challenges were identified in the survey and case examples:

- In meeting the needs of the range of service types offered, the spare ratio must be sufficient within the

sub-fleet(s) of vehicles that support each service type, with appropriate specialized vehicle and accessory requirements. All buses in an entire fleet are not necessarily interchangeable in supporting all service types.
- Meeting the intensive and intermittent nature of some of the special service requirements has taxed bus fleets and their spare vehicles.
- Extreme high and low temperatures, other severe climatic conditions, and in some cases altitude can all take a toll on bus performance and reliability. Weather-related and shorter-term issues include non-starts, cold buses, problems with air, heating, and cooling system, suspension issues, and, with snow or ice, increased accidents involving buses. Many longer-term winter weather impacts are related to salt corrosion.
- Small and outdated maintenance facilities have limited agencies' capacity to handle growing and diverse fleets, including the specialized needs of articulated and alternatively fueled buses (e.g., compressed natural gas). The difficulty of expanding and building new facilities in developed urban areas further constrains the efficient expansion of fleet maintenance capacity.
- The new bus technologies have increased requirements for preventive maintenance and repair procedures on increasingly complex vehicles.
- Attracting and retaining qualified labor (both technicians and management) is very difficult in many areas, not only in terms of the numbers of new employees needed but also the specialized technical skills required.
- There are numerous unmet training needs resulting from lack of resources or available trainers, including:
  - Soft skills (use of computer and software memo-writing skills, record keeping, etc.)
  - Hybrid training resulting from a lack of available trainers at the original equipment manufacturer level and limited employee training availability during peak service times
  - Some major in-house and/or vendor-provided component training (including refresher sessions) missed because of a lack of manpower to fill in while technicians are in training
  - Quality assurance not adequately addressed because of a lack of training staff.

PROMISING PRACTICES

To address some the challenges listed previously and others concerns, survey respondents and case example agencies suggested that sustainable funding for the timely replacement, rehabilitation, and overhaul of aging, high-mileage buses; improved vehicle performance and reliability; increased staffing and training resources; and facility upgrades would all be beneficial to cost-effective fleet management and the optimization of spare ratios.

In addition to these general suggestions, several agencies shared promising practices and strategies, based on their own lessons learned, reporting that:

- It is important to create and maintain a culture of discipline and collaboration across all departments (e.g., maintenance, operations, planning) to manage the fleet within the given parameters of service demands, vehicle mix, funding, staffing levels, etc. Communication is key to preventing departments working in isolation "as silos," without coordination, cooperation, or information-sharing. Focus and close supervision are also essential to managing small sub-fleet spares and facilitating inter-departmental resource sharing and assistance.
- Avoiding large bus purchases whenever feasible is a sound practice. If all buses in a fleet reach the age of lessened reliability and require more frequent maintenance at the same time, it can greatly impact the spare ratio needs. Replacing buses in smaller groups reduces the likelihood that large numbers of vehicles will require intensive maintenance and/or retirement at the same time. At the end of the useful life of a large number of buses, an equally large group of replacements must be funded, procured, and commissioned—another significant challenge involving multiple critical elements and durations, such as: technical specification development (three to six months); governing board approval for release of bid or request for proposal package (one to two months); bid processing time (two months); board and legal review of award (two to three months); issuance of purchase order (one to 10 weeks, depending on pre-award approval and funding); and vehicle manufacture and delivery. Original equipment manufacturers of heavy-duty transit buses typically have a 12- to 18-month time frame from purchase order to delivery.
- Given this lengthy process, it is helpful to reduce the frequency of bus procurements through longer-term contracts with a single manufacturer. This allows the purchase of smaller numbers of buses over an extended period of time, also facilitating greater fleet homogeneity with fewer suppliers and specification changes.
- Breaking up the new bus purchases and old bus retirements into smaller orders is also more efficient in terms of spreading out staff time, because commissioning and de-commissioning buses is a very labor-intensive process requiring the transfer of systems, equipment, and numerous other electronic and mechanical on-board assets.
- It is prudent to keep the bus fleet as homogenous and uniform as possible, with a limited number of different bus types/sizes/manufacturers and fuel/propulsion technologies, allowing for easier replacement and contributing to a lower spare ratio. Stocking parts, providing training, and conducting specialized maintenance for multiple, unique sub-fleets can be difficult and expensive.

- It is important to conduct the highest level of preventive and "preemptive" maintenance feasible, proactively maintaining buses to a high standard. For example, maintaining air system driers year-round to make sure the systems stay dry for the winter can prevent freeze ups; maintaining auxiliary fuel heaters year-round ensures heating systems work when the temperatures drop; and more intensively focusing on springtime radiator washing can avoid buses overheating in the summer. Wherever possible, avoid the trap of seeming to save money by doing the bare minimum required for preventive maintenance, then facing higher expenses later in the form of bus failures, service interruptions, and spare bus constraints. To minimize impact on peak-vehicle requirements, it is beneficial to schedule as many of these preemptive maintenance activities as possible on weekends or midday.
- Assigning service trucks to perform repairs in the field, either at a scheduled meeting place en route or on-site for a stalled bus, can minimize spare bus change-outs. Real-time communication allows for quick adaptability for addressing issues.
- A strong maintenance training program has a very high return on investment in terms of cost-effectively managing the fleet and the spare bus ratio. In addition, the training program is critical to ensuring that the maintenance staff has the capabilities and skills to support the fleet's rapidly changing technologies.
- Using bus mock-ups for maintenance training rather than taking a revenue coach out of service minimizes the draw on available spare buses. It may be possible to use retired buses as mock-ups, but their value as a training aid is often limited because of outdated technology.
- Use of the contingency fleet buses and spares available in off-peak period can support training needs while minimizing impacts to maintenance activities. The inactive contingency fleet can be helpful in getting new drivers oriented and initially trained. The use of active fleet coaches during the off-peak periods for driver and mechanic training can help keep spare buses available for peak-period demands.
- Whenever feasible, design interoperability and flexibility into new services and branding schemes. This will make it possible to "lend" buses from different sub-fleets (beyond the ones dedicated for a particular service) to other services during periods of unusually high-demand and/or other operational challenges.
- When evaluating and approving new transit services and/or new bus technologies, it would be beneficial to perform a full life-cycle cost analysis, including a realistic assessment of the additional spare bus requirements to support the sub-fleet and services.

Finally, true effectiveness in the optimization of spare ratios begins with governing board and executive management commitment to a "leaner" fleet, and the dedication of sustainable financial resources, staffing support, and internal policies to support that commitment.

SUGGESTIONS FOR FURTHER RESEARCH

As noted in the literature review, there has been very limited research conducted on the management and optimization of spare bus fleets and spare ratios. There is little, if any, guidance to assist practitioners (i.e., transit agency maintenance, operations, and planning staffs) in "right-sizing" their spare bus fleets and making their overall vehicle maintenance and deployment more efficient.

To this end, the following suggestions for additional research and development are offered:

- A methodology (including tools, templates, and models) for fleet maintenance, operations, engineering, planning, and finance department departments to use in determining the optimal number of spare vehicles relative to peak fleet needs (i.e., their spare ratio), integrating the various unique factors, conditions, services, fleet sizes, and practices of a particular transit agency. This could include an evaluation tool that takes into consideration the weighted effects of all of the criteria mentioned throughout this document that impact the ability of an agency to deliver reliable service, including, but not limited to, daily maintenance requirements, training bus needs, special events and displays, other special requests for buses, and marketing/branding programs.
- Opportunities to improve bus fleet reliability and performance, including best maintenance practices that provide the greatest return on investment
- A comparative analysis of alternative fuel and energy propulsion systems, including full life-cycle costs, benefits, performance, reliability, and effective practices among fleet managers operating vehicles with these systems (including actual experience related to spare vehicle support needs)
- Best practices and tools for the optimization of maintenance staffs, including, but not limited to:
  - Staffing levels, organization, and assignment
  - Workforce productivity and time standards
  - Work planning
  - Improved preventive maintenance approaches and diagnostics
  - Technical skill development and training
- Methods and strategies to improve inter-departmental collaboration and "the breaking down of silos" (e.g., between maintenance, operations, and planning departments)
- Best labor practices, including creative collective bargaining agreement language that has been negotiated in the United States and Canada resulting in improved fleet maintenance productivity and performance

- Creative procurement practices to enable longer-term purchasing under a single “umbrella” contract, enabling greater uniformity of buses and major components over an extended period
- A review of all the implications that the wave of “baby boomer” retirements may have on skilled maintenance staffing, spare bus fleet needs, and resulting spare ratios; and solutions to address these implications
- International experience and best practices in bus fleet operations and maintenance management, with a special focus on optimizing fleet size and controlling costs.

Appendix C contains a proposed research problem statement for submittal to the TCRP program for potential funding as a project, encompassing some of the suggestions cited previously.

In closing, continuing the dialogue between APTA and the FTA on exploring potential changes to the FTA spare ratio guidelines would be highly constructive. This conversation could enable the exploration of opportunities to meet the challenges facing the nation’s transit operators while addressing such federal interests as prudent investment of federal transit dollars, transit asset management, and state of good repair.

ACRONYMS

BRT	Bus rapid transit
CTA	Chicago Transit Authority
WT	City of Winnipeg Transit Department/Winnipeg Transit
CNG	Compressed natural gas
DART	Dallas Area Rapid Transit
RTD	Denver Regional Transit District
LNG	Liquefied natural gas
MMIS	Maintenance Management Information System
OEM	Original equipment manufacturer
PM	Preventive maintenance
VTA	Santa Clara Valley Transportation Authority
TRIS	Transportation Research Information Service
VAMS	Vehicles Available for Maximum Service
VOMS	Vehicles Operated in Maximum Service

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Branch, P., *National Bus Spare Ratio Study*, Federal Transit Administration, Washington, D.C., 1993.

Iskander, W. and M. Jaraiedi, *Evaluation of the Spare Ratio Concept in the Management of Transit Rolling Stock*, Urban Mass Transportation Administration, Washington, D.C., 1988.

Iskander, W., M. Jaraiedi, and S. Niaki, "Simulation Study to Evaluate Spare Ratios in Bus Transit Systems," *Transportation Research Record 1221*, Transportation Research Record, National Research Council, Washington, D.C., 1989, pp. 77–87.

Jaraiedi, M. and W. Iskander, "Statistical Evaluation of Spare Ratio in Transit Rolling Stock," *Transportation Research Record 1221*, Transportation Research Record, National Research Council, Washington, D.C., 1989, pp. 88–90.

Li, T., A. Gan, and F. Cevallos, "Characteristics of Bus Transit Vehicles in the United States: How They Have Changed Over a Quarter Century," presented at the 53rd Annual Transportation Research Forum, Tampa, Fla., Mar. 15–17, 2012.

Minkoff, M., *Bus Fleet Management in an Era of Increasing Technical Complexity: Analysis of Bus Fleet Spare Ratios*, TCRP Project J-06, Task 73, Transportation Research Board of the National Academies, Washington, D.C., 2009.

Pierce, J. and E. Moser, *TCRP Synthesis 11: System-Specific Spare Bus Ratios*, Transportation Research Record, National Research Council, Washington, D.C., 1995.

Schiavone, J. and X. Wang, *Method and Processes for Transit Training Metrics and Return on Investment*, Transportation Learning Center, Silver Spring, Md., 2011.

BIBLIOGRAPHY

Following are some additional related reference materials that may be of value to transit agencies in their efforts to improve fleet maintenance programs, transit asset management practices, and other related activities. These materials contain practices and strategies that could, directly or indirectly, enable transit organizations to better manage their fleets and spare bus requirements:

Dolce, J. E., *Analytical Fleet Maintenance Management*, 3rd ed., SAE International, Warrendale, Penn., 2009.

Goodwill, J. and D. Sapper, *Florida Bus Maintenance Staffing Practices*, Center for Urban Transportation Research, Tampa, Fla., 2011.

Maze, T. H., *Bus Fleet Management Principles and Techniques: Final Report*, U.S. Department of Transportation, Washington, D.C., 1987.

Schiavone, J., *A Guidebook for Developing and Sharing Transit Bus Maintenance Practices*, Transportation Research Board of the National Academies, Washington, D.C., 2005.

Transit Asset Management Practices: A National and International Review, Federal Transit Administration, Washington, D.C., June 2010.

Given the linkage between effective bus fleet maintenance/management and the FTA's *Transit Asset Management* and *State of Good Repair* initiatives, the FTA website provides access to several excellent reference materials. Please refer to the following hyperlinks for more information:

http://www.fta.dot.gov/13248.html

http://www.fta.dot.gov/documents/MAP-21_Fact_Sheet_-_Transit_Asset_Management.pdf.

APPENDIX A

TCRP Synthesis Survey Questionnaire: System Specific Spare Ratios

WELCOME!

Dear Survey Recipient,

The American Public Transportation Association (APTA), through its nonprofit research organization, the Transit Development Corporation, Inc. (TDC), is cooperating in a research project to prepare a synthesis of current practice on System-Specific Spare Bus Ratios. This is part of the Transit Cooperative Research Program (TCRP), managed by the Transportation Research Board (TRB) in cooperation with the Federal Transit Administration (FTA) and TDC. TCRP syntheses provide practical information and guidance for transit agencies of all sizes in profiling innovative and successful practices, lessons learned, and gaps in information.

The purpose of this project is to update the findings of *TCRP Synthesis 11* on Spare Bus Ratio practices, published in 1995. The complexity and challenges facing today's transit operators have changed dramatically over the last 18 years. This project will focus on providing current guidance to transit agencies. The final report, to be published by TRB, will provide information on various factors affecting bus spare ratio levels and agency approaches taken to reduce their spare ratios—and the results.

This survey questionnaire is being distributed to transit agencies that operate bus fleets. If you are not the appropriate person at your agency to complete this survey, please forward it to the correct person.

The survey questions are designed to gather information concerning your agency's bus fleet(s) that are used to deliver *fixed-route and other scheduled general public transit services.* This survey does *not* cover ADA paratransit services. When reporting fleet information and related characteristics, please do *not* include vehicles used for ADA paratransit services. As well, please do *not* include vanpool vehicles.

Please complete and submit this survey questionnaire by Monday, February 18, 2013. If you have any questions, please do not hesitate to contact our principal investigator Martin Minkoff at martin.minkoff@icfi.com or (206) 817-4286.

Thank you very much for participating in this survey!

CONTACT INFORMATION OF PERSON COMPLETING SURVEY

1) Please list the name of your organization and the contact information for the person completing this survey.

First Name*: ____________________

Last Name*: ____________________

Title*: ____________________

Agency Name*: ____________________

Street Address*: ____________________

Apt/Suite/Office: ____________________

City*: ____________________

State/Province*: ____________________

Zip/Postal Code*: ____________________

Country*: ____________________

E-mail Address*: ____________________

Phone Number*: ____________________

Fax Number: ____________________

Mobile Phone: ____________________

Agency Website URL (Home Page): ____________________

YOUR AGENCY'S FLEET DESCRIPTION

2) Please check the following classifications that apply to your agency's active bus fleet:

   [ ] Directly operated (and maintained) bus services

   [ ] Contracted (purchased transportation) bus services

3) Please check below each type of bus that your agency has in its DIRECTLY OPERATED active bus fleet:

   [ ] Less-than-30-foot Bus

   [ ] 30-foot Bus

   [ ] 35-foot Bus

   [ ] 40-foot Standard Bus

   [ ] Over-the-Road (3 Axle) Bus

   [ ] 60-foot Articulated Standard Bus

   [ ] Double-Decker Bus

   [ ] Other (please specify):

   [ ] Not Applicable

4) Please check below each type of bus that your agency has in its CONTRACTED active bus fleet:

   [ ] Less-than-30-foot Bus

   [ ] 30-foot Bus

   [ ] 35-foot Bus

   [ ] 40-foot Standard Bus

   [ ] Over-the-Road (3 Axle) Bus

   [ ] 60-foot Articulated Standard Bus

   [ ] Double-Decker Bus

   [ ] Other (please specify):

   [ ] Not Applicable

5) As applicable, please enter the following for your DIRECTLY OPERATED bus fleet by year (enter zeroes for any year not operated):

	Vehicles Available for Maximum Service (i.e., your Total Active Fleet)	**Vehicles Operated in Maximum Service (i.e., your Peak-Service Fleet)**	**Annual Vehicle Miles**
2012	___	___	___
2011	___	___	___
2010	___	___	___
2009	___	___	___
2008	___	___	___

6) As applicable, please enter the following for your CONTRACTED bus fleet below by year (enter zeros for any year not operated):

	Vehicles Available for Maximum Service (i.e., your Total Active Fleet)	**Vehicles Operated in Maximum Service (i.e., your Peak-Service Fleet)**	**Annual Vehicle Miles**
2012	___	___	___
2011	___	___	___
2010	___	___	___
2009	___	___	___
2008	___	___	___

7) Please enter the Spare Ratio (%) for your Directly Operated Bus Fleet, your Contracted Bus Fleet, and your (combined) Total Fleet (as each may be applicable) for each of the years indicated below. Please enter zeroes for any year not operated.

	Directly Operated	**Contract (Purchased Transportation)**	**TOTAL (Directly Operated and Contracted)**
2012	___	___	___
2011	___	___	___
2010	___	___	___
2009	___	___	___
2008	___	___	___

8) Please describe the method you use to calculate the spare ratio(s).

9) If you CONTRACT for bus services, what spare ratio do you recommend or require the contractor to maintain (if applicable)?

Recommended: ________________________________

Required: ____________________________________

10) Beyond your spare buses, do you maintain an inactive contingency fleet that can be mobilized if needed for emergencies?

( ) Yes

( ) No

11) How many buses are in your inactive contingency fleet?

____

OTHER FLEET CHARACTERISTICS

12) As applicable, for each year, please list the average age and average mileage of your DIRECTLY OPERATED fixed-route bus fleet (Vehicles Available for Maximum Service)? Enter zeroes for any year not operated.

	Average Age	**Average Mileage**
2012	___	___
2011	___	___
2010	___	___
2009	___	___
2008	___	___

13) As applicable, for each year please list the average age and average mileage of your CONTRACTED fixed-route bus fleet (Vehicles Available for Maximum Service)? Enter zeroes for any year not operated.

	Average Age	**Average Mileage**
2012	___	___
2011	___	___
2010	___	___
2009	___	___
2008	___	___

14) Has the age or mileage of your fleet affected your spare bus needs and fleet spare ratio?

( ) Yes

( ) No

15) Please briefly explain how the age and/or mileage of your fleet has affected your spare bus needs (and if this has changed over the past five years).

16) For each of the years noted below, please check each advanced technology system that is/was present within your ENTIRE BUS FLEET (both directly operated and contracted out) or check "not applicable":

	2012	**2011**	**2010**	**2009**	**2008**	**Not Applicable**
On-Board Electronic Fare Collection	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Automatic Vehicle Location (AVL)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Bus Stop Enunciation	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Automatic Passenger Counters (APC)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Digital Radio Communication	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Data Transmission (incl. Mobile Data Terminals)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Wireless Internet	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
On-Board Surveillance	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Advanced Emissions Control	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Regenerative Braking	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Electronic Head Signs	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Closed Area Networks	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Remote Diagnostics	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Hazard Detection/Response Systems	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other (refer to next question)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

17) If you specified "other" in previous question, please describe other advanced technology systems contained in your bus fleet and the year in which they were introduced:

	Advanced Technology System	**Year Introduced**
Other	___	___
Other	___	___
Other	___	___
Other	___	___

18) Has the presence of these advanced technology systems affected your spare bus needs and fleet spare ratio?

( ) Yes

( ) No

19) Please briefly explain how these advanced technology systems have affected your spare bus needs and fleet spare ratio (and if this has changed over the past five years).

20) Please list the TOTAL number of vehicles powered by each fuel/energy system represented in your DIRECTLY OPERATED bus fleet and your CONTRACTED bus fleet (if applicable):

	2012	**2011**	**2010**	**2009**	**2008**
Gasoline	___	___	___	___	___
Diesel	___	___	___	___	___
CNG	___	___	___	___	___
LNG	___	___	___	___	___
Propane	___	___	___	___	___
Hybrid-Electric (Gasoline)	___	___	___	___	___
Hybrid-Electric (Diesel)	___	___	___	___	___
Battery-Electric	___	___	___	___	___

	2012	2011	2010	2009	2008
Fuel Cell	___	___	___	___	___
Electric Trolley (Overhead Catenary)	___	___	___	___	___
Other (refer to next question)	___	___	___	___	___

21) If you specified "other" in previous question, please describe other fuel/energy system and the respective number of buses in each year below:

	Fuel/Energy System	2012	2011	2010	2009	2008
Other	___	___	___	___	___	___
Other	___	___	___	___	___	___
Other	___	___	___	___	___	___
Other	___	___	___	___	___	___

22) Have the fuel/energy systems present in your fleet affected your spare bus needs and spare ratio?

( ) Yes

( ) No

23) Please briefly explain how the fuel/energy systems in your fleet have affected your spare bus needs and spare ratio (and if this has changed over the past five years).

YOUR AGENCY'S SERVICE AND OPERATING ENVIRONMENT

24) For each year, what type(s) of regularly scheduled transit services have been provided with your bus fleet? Please check all that apply or not applicable.

	2012	2011	2010	2009	2008
Bus Rapid Transit (BRT)	[ ]	[ ]	[ ]	[ ]	[ ]
Commuter Express (non-BRT)	[ ]	[ ]	[ ]	[ ]	[ ]
Regional Trunk	[ ]	[ ]	[ ]	[ ]	[ ]
Local Route	[ ]	[ ]	[ ]	[ ]	[ ]
Neighborhood Circulator/Feeder	[ ]	[ ]	[ ]	[ ]	[ ]
Shuttle	[ ]	[ ]	[ ]	[ ]	[ ]
Other (refer to next question)	[ ]	[ ]	[ ]	[ ]	[ ]
Not applicable	[ ]	[ ]	[ ]	[ ]	[ ]

25) If you specified "other" in previous question, please describe other types of regularly scheduled transit services provided with your bus fleet and the year in which they were introduced:

	Type of Service	Year Introduced
Other	___	___
Other	___	___
Other	___	___
Other	___	___

26) Has the provision of these types of services affected your spare vehicle needs and fleet spare ratio?

( ) Yes

( ) No

27) Please briefly explain how providing these types of services have affected your spare vehicle needs and fleet spare ratio (and if this has changed over the past five years).

28) What specialized features are REQUIRED on buses in your fleet in order to operate the mix of transit services your agency provides?

Please check as many as applicable.

[ ] High passenger-carrying capacity more than a standard 40' bus

[ ] Special exterior branding with unique paint scheme

[ ] Exterior wood trim (e.g., for Trolley-Replicas)

[ ] Ability to maneuver in confined areas

[ ] Luggage racks/storage

[ ] Premium seating and other interior amenities

[ ] Low floor

[ ] More than one door

[ ] Other 1

[ ] Other 2

Other 1 (please specify): ____

Other 2 (please specify): ____

29) Has a lack of available buses equipped with these required specialized features affected your ability to meet the daily pullout requirements of any of your services?

( ) Yes

( ) No

30) Please briefly explain how the lack of available buses equipped with these required specialized features has affected your ability to meet the daily pullout requirements of any of your services?

31) For each year, what type(s) of special or intermittent service needs have been met with your fixed-route fleet?

Please check all that apply for each year.

	2012	**2011**	**2010**	**2009**	**2008**
Special Event or Exhibition	[ ]	[ ]	[ ]	[ ]	[ ]
Back-Up "Bus Bridges" for Rail Interruptions	[ ]	[ ]	[ ]	[ ]	[ ]
"Plug Buses" for overloads and/or schedule compliance/"catch-up"	[ ]	[ ]	[ ]	[ ]	[ ]
Training	[ ]	[ ]	[ ]	[ ]	[ ]
Other Emergency or Special Need	[ ]	[ ]	[ ]	[ ]	[ ]
None of the above or Not Applicable	[ ]	[ ]	[ ]	[ ]	[ ]

32) Has meeting these special or intermittent service requirements affected your spare vehicle needs and fleet spare ratio?

( ) Yes

( ) No

33) Please briefly explain how meeting these special or intermittent service requirements has affected your spare vehicle needs and fleet spare ratio (and if this has changed over the past five years).

34) We need the Peak-to-Base Ratio of your DIRECTLY OPERATED TRANSIT SERVICES and your CONTRACTED TRANSIT SERVICES—as each may be applicable. To enable us to calculate this ratio, please specify the highest number of buses required during the a.m. and p.m. peak periods and the lowest bus requirement during the base period (i.e., the off-peak period in between the a.m. and p.m. peak periods) for your DIRECTLY OPERATED and/or your CONTRACTED SERVICES, as applicable. For example, if the highest number of peak vehicles required is 251 and the lowest number of base vehicles required is 112, please enter those numbers respectively. (We will then use those numbers to compute the peak-to-base ratio—which in this example would be 2.24)

	a.m. Peak Period Highest Bus Requirement	p.m. Peak Period Highest Bus Requirement	Base Period Lowest Bus Requirement
Directly Operated Service (if applicable)	___	___	___
Contracted Service (if applicable)	___	___	___

35) Has your agency's peak-to-base ratio, and the resulting available bus maintenance time window, affected your spare bus needs and fleet spare ratio?

( ) Yes

( ) No

36) Please briefly explain how your agency's peak-to-base ratio, and the resulting available bus maintenance time window, has affected your spare bus needs and fleet spare ratio.

37) Please describe any unique climatic or other environmental conditions under which your agency operates transit services.

[ ] Extreme heat

[ ] Extreme humidity

[ ] Extreme cold

[ ] Heavy snow and/or ice

[ ] Salt or other corrosive elements

[ ] Steep hills

[ ] Extremely rough pavement

[ ] Other

[ ] None

38) If there are "other" unique climatic/environmental operating conditions you deal with that were not listed, please describe them below:

Other: ___________________________

Other: ___________________________

Other: ___________________________

Other: ___________________________

39) Have these climatic and/or environmental conditions affected your spare vehicle needs and fleet spare ratio?

( ) Yes

( ) No

( ) Not Applicable

40) Please briefly explain how these climatic and/or environmental conditions have affected your spare vehicle needs and fleet spare ratio.

41) Please identify the duty cycle categories under which your fleet operates and the relative proportion (%) of your fleet operating within each category.

Heavy (intensive stop/start/dwell): ___________________________

Medium (moderate stop/start/dwell): ___________________________

Light (infrequent stop/start/dwell): ___________________________

42) Have the duty cycles under which the buses in your fleet operate affected your spare bus needs and fleet spare ratio?

( ) Yes

( ) No

43) Please briefly explain how the duty cycles, under which the buses in your fleet operate, have affected your spare bus needs and fleet spare ratio.

44) Please indicate the relative degree to which each factor below influences the number of spare buses that your agency is required to maintain.

	No influence	**Limited influence**	**Moderate influence**	**Significant influence**	**Not Applicable**
Alternative Fuel/Energy Systems in Fleet	( )	( )	( )	( )	( )
Special Vehicle Needs or Features Required on Certain Routes	( )	( )	( )	( )	( )
Age or Mileage of the Fleet	( )	( )	( )	( )	( )
Advanced On-Board Technology Systems	( )	( )	( )	( )	( )
Intensity of Duty Cycles	( )	( )	( )	( )	( )
Requirements to meet special service demands (e.g., emergencies, rail interruption support, “plug” buses for overloads or schedule catch-up, etc.)	( )	( )	( )	( )	( )
Peak-to-Base Ratio (and resulting available bus maintenance time window)	( )	( )	( )	( )	( )
Other (if not listed, refer to next question)	( )	( )	( )	( )	( )

45) If you specified “other” on the previous question, please describe those additional factors that influence the number of spare buses that your agency is required to maintain. Please also indicate the relative level of influence below for each factor.

	Description of Additional Factor	**Relative Level of Influence on Spare Bus Needs (1 = No influence; 2 = Limited influence; 3 = Moderate influence; and 4 = Significant influence)**
Other	___	___
Other	___	___
Other	___	___
Other	___	___

YOUR AGENCY’S FLEET MAINTENANCE PROGRAMS

46) (If applicable) what is your DIRECTLY OPERATED fleet ratio of technicians-to-buses? Please include technicians who actually work on the vehicle and its systems and sub-systems; do not include fuelers, cleaners, tire-servicers, etc. (for example, if you have 44 technicians and 210 buses, divide 44 by 210, and then enter 0.21).

____

47) (If applicable) what is your CONTRACTED fleet ratio of technicians-to-buses? Please include technicians who actually work on the vehicle and its systems and sub-systems; do not include fuelers, cleaners, tire-servicers, etc. (for example, if you have 44 technicians and 210 buses, divide 44 by 210, and then enter 0.21).

____

48) Please fill in the table below, as applicable, listing the type of training that is regularly provided to your maintenance staff within the appropriate cell.

	For New Buses Only	**For All Buses**	**Other**
In-House Training	___	___	___
Manufacturer/Vendor Support	___	___	___
Other Outsourced Training	___	___	___

49) Please indicate any training needs that are not being addressed and why (e.g., lack of funding, not enough staff to back-fill technicians while in training, etc.).

50) Does your organization have a bus replacement or major rehabilitation schedule?

( ) Yes

( ) No

51) Under this schedule, at what age (in years) is a bus to be replaced or rehabbed? Please enter as applicable.

	Heavy Duty Large Bus (30' to 48', and 60' artic)	**Medium-to-Light Duty Small Bus (16' to 30', including cutaways)**	**Other**
Replaced	___	___	___
Rehabbed	___	___	___
If neither, enter zero	___	___	___

52) As needed, please provide any additional clarifying information concerning your agency's bus replacement/rehabilitation schedule.

53) Please select the answer(s) below that best describe the criteria under which a bus is pulled from service (check all that apply).

[ ] Any defect that precludes the safe operation of the bus

[ ] Any defect that limits the accessibility of the bus (e.g., malfunctioning lift, ramp, kneeling mechanism, etc.)

[ ] Any defect that adversely affects customer comfort (e.g., malfunctioning air conditioning or heating system)

[ ] Any cosmetic damage or blemish (e.g., body dents, graffiti, scratched windows, torn seat (etc.)

[ ] Lack of cleanliness (based on acceptable agency standard)

[ ] Any defect that limits the collection of revenue (e.g., malfunctioning farebox, smartcard reader, etc.)

[ ] Any defect that limits customer information (e.g., malfunctioning head-signs, automated stop announcement

[ ] Other

54) Please indicate any physical constraints at your maintenance facilities or depots that limit the functionality or flexibility of your maintenance activities.

[ ] Limited number of maintenance bays or lifts

[ ] Need to shuttle vehicles between facilities for certain maintenance needs (e.g., major component overhaul, PMs, paint/body, etc.)

[ ] Inability to support certain bus types (e.g., artics, CNG fueling, etc.)

[ ] Other

[ ] None

55) Have these facility constraints affected your spare vehicle needs and fleet spare ratio?

( ) Yes

( ) No

( ) Not Applicable

56) Please briefly explain how these facility constraints have affected your spare vehicle needs and fleet spare ratio.

57) By year, what has been your DIRECTLY OPERATED fleet's average annual mean distance between mechanical failures? Please enter zero for any year not in operation.

2012: ___________________________

2011: ___________________________

2010: ___________________________

2009: ___________________________

2008: ___________________________

58) By year, what has been your CONTRACTED fleet's average annual mean distance between mechanical failures (if applicable)? Please enter zero for any year not in operation.

2012: ___________________________

2011: ___________________________

2010: ___________________________

2009: ___________________________

2008: ___________________________

59) For purposes of your calculations, please briefly define "mechanical failure."

60) Please indicate the relative degree to which each factor below influences the number of spare buses that your agency is required to maintain.

	No influence	**Limited influence**	**Moderate influence**	**Significant influence**	**Not Applicable**
Level of Maintenance Staffing in Key Skill Areas	( )	( )	( )	( )	( )
Level of Training	( )	( )	( )	( )	( )
Fleet Replacement/Rehab Schedule	( )	( )	( )	( )	( )
Out of Service Criteria (when bus is removed)	( )	( )	( )	( )	( )
Fleet Reliability (measured by mean distance between mechanical failures)	( )	( )	( )	( )	( )
Maintenance Facility Constraints (at one or more garages/depots)	( )	( )	( )	( )	( )
Other (if not listed, refer to next question)	( )	( )	( )	( )	( )

61) If you specified "other" on the previous question, please describe those additional factors that influence the number of spare buses that your agency is required to maintain. Please also indicate the relative level of influence below for each factor.

	Description of Additional Factor	**Relative Level of Influence on Spare Bus Needs (1 = No influence; 2 = Limited influence; 3 = Moderate influence; and 4 = Significant influence).**
Other	___	___
Other	___	___
Other	___	___
Other	___	___

62) Please indicate the relative degree to which each element of your maintenance program below influences the number of spare buses that your agency is required to maintain.

	No influence	**Limited influence**	**Moderate influence**	**Significant influence**	**Not Applicable**
Preventative Maintenance (PM) Inspections (and resulting action)	( )	( )	( )	( )	( )
Major component repair/rebuild	( )	( )	( )	( )	( )
Scheduled mid-life overhauls	( )	( )	( )	( )	( )
Running Repair	( )	( )	( )	( )	( )
Body and Paint	( )	( )	( )	( )	( )
Daily Servicing (i.e., fueling, cleaning, etc.)	( )	( )	( )	( )	( )
Other (if not listed, refer to next question)	( )	( )	( )	( )	( )

63) If you specified "other" on the previous question, please describe those additional maintenance program elements that influence the number of spare buses that your agency is required to maintain. Please also indicate the relative level of influence below for each element.

	Description of Additional Element	**Relative Level of Influence on Spare Bus Needs (1 = No influence; 2 = Limited influence; 3 = Moderate influence; and 4 = Significant influence).**
Other	___	___
Other	___	___
Other	___	___
Other	___	___

YOUR AGENCY'S FINANCIAL CHALLENGES

64) Have financial challenges impacted your agency's spare bus needs and spare ratio?

( ) Yes

( ) No

65) Please indicate specific challenges (check all that apply):

[ ] Reduced maintenance staffing levels

[ ] Reduced dollars available for needed training

[ ] Transit service reductions resulting in unused vehicles (and expansion of the spare vehicle fleet)

[ ] Reduced capital dollars available for needed bus replacement

[ ] Reduced funds available for state of good repair

[ ] Other challenges (please list in next question)

66) Please briefly list any other financial challenges not listed above that have impacted your agency's spare bus needs and spare ratio?

67) Has your agency exceeded the FTA's 20% spare ratio guideline in any of the past five years?

( ) Yes

( ) No

68) If so, please describe the FTA's response (e.g., a full waiver, a conditional waiver, requirement to develop an action plan to meet the 20% threshold, other)?

69) CANADIAN SYSTEMS ONLY: What has been the impact of federal and/or provincial funding on your fleet spare ratio?

YOUR AGENCY'S APPROACHES TO REDUCING ITS SPARE RATIO

70) Is your current spare ratio sufficient to meet your agency's maximum operating requirements AND your optimal maintenance program?

( ) Yes

( ) No

71) Please list the top three reasons why your fleet's current spare ratio is NOT sufficient:

Reason 1: ____________________________

Reason 2: ____________________________

Reason 3: ____________________________

72) Has your agency been able to reduce its spare ratio over the past 5 years?

( ) Yes

( ) No

73) Please describe the actions taken to accomplish this, and the results (including the spare ratio change):

74) Over the past 5 years, have you taken affirmative actions toward reducing your fleet's spare ratio that did not work?

( ) Yes

( ) No

75) Please briefly describe the action(s), the results, and any lessons learned:

76) Do you believe that a 20% spare ratio for your fleet is realistic for your agency?

( ) Yes

( ) No

77) If not, please explain why:

78) What changes in practice, policy, or additional resource(s) would best improve your agency's ability to reduce its fleet spare ratio?

YOUR AGENCY'S INTEREST IN BEING A CASE STUDY

79) Would your agency be interested in being one of four case examples to be developed for this Synthesis Report? (It would entail a telephone interview; you would have the ability to review, and correct any inaccuracies in, your case study description before final printing of the Synthesis Report).

( ) Yes

( ) No

( ) Maybe—would like more information

THANK YOU FOR YOUR TIME AND INSIGHTS!

Thank you for completing and submitting the survey via the web. Your timely and complete response is very important to this project and its usefulness to the transit industry.

If you have any questions or concerns following submittal, please contact Martin Minkoff, ICF International via e-mail at: martin.minkoff@icfi.com or telephone at (206) 817-4286.

Thank you!

APPENDIX B

Participating Transit Agencies

Table B1 contains the 38 transit agency respondents that participated in the Synthesis Survey, sorted by fleet size group, 2012 Vehicles Available for Maximum Service (VAMS), and business model (i.e., directly operated vs. contract operation).

TABLE B1
TRANSIT AGENCIES THAT PARTICIPATED IN THIS SYNTHESIS SURVEY OF SPARE BUS RATIO PRACTICES

Bus Fleet Size Category	Agency	Location	2012 Vehicles Available for Maximum Service	Directly Operated	Contracted
SMALL (25–99 buses)					
	Sumter County Transit (SCT)	Wildwood FL	25		X
	Connect Transit	Bloomington, IL	29	X	
	Valley Regional Transit (VRT)	Boise, ID	43	X	
	CityBus	Culver City, CA	52	X	
	Star Metro	Tallahassee, FL	67	X	
	Capital Area Transportation Authority (CATA)	Lansing, MI	96	X	
MEDIUM (100–249 buses)					
	Lane Transit District (LTD)	Eugene, OR	117	X	
	Regional Transportation Authority	New Orleans, LA	137		X
	Central New York Regional Transit Authority (CENTRO)	Syracuse, NY	167	X	
	Riverside Transit Agency (RTA)	Riverside, CA	171	X	X
	London Transit	London, ON, Canada	192	X	
	Long Beach Transit (LBT)	Long Beach, CA	220	X	
	Pierce Transit	Tacoma, WA	234	X	X
	SunTran	Tucson, AZ	237	X	
LARGE (250–499 buses)					
	San Diego Metropolitan Transit System (MTS)	San Diego, CA	260	X	
	Greater Dayton Regional Transit Authority	Dayton, OH	263	X	
	San Mateo County Transit District (SamTrans)	San Mateo, CA	287	X	X
	Central Ohio Transportation. Authority (COTA)	Columbus, OH	308	X	
	Regional Transportation Commission (RTC) of Southern Nevada	Las Vegas, NV	397		X
	Santa Clara Valley Transportation Authority (VTA)	San Jose, CA	426	X	
	Greater Cleveland Regional Transit Authority (GCRTA)	Cleveland, OH	452	X	

(*continued on next page*)

TABLE B1
(*continued*)

Bus Fleet Size Category	Agency	Location	2012 Vehicles Available for Maximum Service	Directly Operated	Contracted
VERY LARGE (500–999 buses)					
	Orange County Transportation Authority (OCTA)	Orange, CA	561	X	X
	City of Winnipeg Transit Department	Winnipeg, MB, Canada	565	X	
	AC Transit	Oakland, CA	569	X	
	TriMet	Portland, OR	594	X	
	Dallas Area Rapid Transit (DART)	Dallas, TX	644	X	
	Port Authority (PA) Transit	Pittsburgh, PA	714	X	
	Miami–Dade Transit (MDT)	Miami, FL	818	X	
	Massachusetts Bay Transportation Authority (MBTA)	Boston, MA	910	X	
	Edmonton Transit	Edmonton, AB, Canada	972	X	
MEGA (>1,000 buses)					
	Denver Regional Transit District (RTD)	Denver, CO	1,003	X	X
	Coast Mountain Bus	Vancouver, BC, Canada	1,107	X	
	King County Metro	Seattle, WA	1,503	X	
	Société de Transport de Montréal (STM)	Montreal, QC, Canada	1,728	X	
	Chicago Transit Authority (CTA)	Chicago, IL	1,792	X	
	Toronto Transit Commission (TTC)	Toronto, ON, Canada	1,857	X	
	New Jersey Transit (NJT)	Newark, NJ	2,382	X	X
	New York City Transit—Department of Buses—Metropolitan Transit Authority (NYCT—MTA)	New York, NY	4,431	X	

APPENDIX C

Proposed TCRP Problem Statement

I. PROBLEM TITLE

Optimizing Spare Bus Fleets through Improved Maintenance and Operational Practices

II. RESEARCH PROBLEM STATEMENT

The TCRP Synthesis of *System-Specific Spare Bus Ratios* (*SA-32*) provided a comprehensive review of the spare bus issues, challenges, and experiences facing U.S. and Canadian transit operators. This research analyzed a number of factors affecting spare bus needs across a wide range of agencies with varied bus fleet configurations, service mixes, and operating environments. It also highlighted several suggested practices for transit operators to consider that would improve the management of their bus fleets and spare ratios—"what could be done." As a TCRP synthesis, however, the practices identified did not get into significant depth regarding "how to do it."

There is a clear need for practical guidance to transit agencies as to how they can implement some of the promising practices identified in the SA-32 Synthesis and other sources, including (but not limited to):

- An evaluation methodology that can be used by transit agency staff in determining the optimal number of spare vehicles required relative to peak fleet needs (i.e., their spare ratio)
- Methods and strategies to improve inter-departmental collaboration and "the breaking down of silos" (e.g., between maintenance, operations, and planning departments)
- Approaches to reallocating more maintenance work to the night shift and other non-peak hours to mitigate spare bus requirements
- Strategies to increase the inter-operability of the fleet to meet agency transit service needs while supporting efficient maintenance practices, such as keeping the fleet as homogeneous as possible
- Improving training and developing work force capacity to address the increasing technological complexity and labor-intensiveness of transit fleet maintenance
- Other promising practices to improve bus fleet management.

III. OBJECTIVE

This research is intended to provide transit professionals with a compendium of best practices, actionable tools, and practical methods with which to improve bus fleet management and optimize spare ratios. Building upon some of the promising practices identified in TCRP Synthesis SA-32—*System-Specific Spare Ratio Update* and other sources, the primary objective is to produce a detailed "how to" guidebook to assist transit agency staff (from such departments as maintenance, operations, engineering, planning, procurement, and finance) in determining the optimal size (and mix) of the spare vehicle fleet and taking cost-effective action to achieve and maintain that fleet level.

IV. RESEARCH PROPOSED

The research would be organized around two key phases (and their respective tasks):

Phase 1: Data Collection, Analysis, and Documentation

- Review literature, including TCRP Synthesis SA-32: *System-Specific Spare Ratios* and other relevant documents
- Analyze relevant National Transit Database (NTD) data
- Canvass and select a broad representation of 10–12 transit agencies (large and small) for in-depth research; these agencies will have been identified as innovators in effectively maintaining a "lean" spare bus fleet relative to their peak pullout (i.e., their spare ratio).
- Develop survey and telephone interview templates for the 10–12 agencies
- Conduct survey and telephone interviews with key executive, maintenance, operations, planning, and other relevant staff; gather data and information on "what they do" and "how they do it"
- Based on surveys and telephone interviews, five of the agencies will be selected for on-site interviews and inter-departmental "focus" groups.
- Analyze the various fleet attributes, transit services, operating environment, and effective practices reported by the surveyed/interviewed agencies, considering the weighted effects of such criteria as daily maintenance requirements; technical training needs; the daily revenue service mix; training bus requirements; special events and displays; special requests for buses; and marketing/branding programs; fleet mix, bus fuel/energy systems; advanced technology systems on-board, average bus age/mileage, etc.
- Document survey and interview information and analysis in a technical memorandum.

2) Develop Draft and Final Guidebook, to include:

- A methodology (including data templates and analytical tools) that can be practically applied by transit agency staff in estimating the optimal mix and number of spare vehicles required (i.e., their spare ratio)
- Action Steps with which to implement practices identified in Phase 1 that can assist agencies in achieving their optimal mix and number (and continuing to improve).
- Draft guidebook review by Panel, with comments addressed in the final guidebook.

V. ESTIMATE OF THE PROBLEM FUNDING AND RESEARCH PERIOD

It is estimated that this project will require $250,000 over an 18-month study period (including three months for review and revision of the draft final report).

VI. URGENCY AND PAYOFF POTENTIAL

The urgency of this proposed research lies in its opportunities to provide tools to transit agencies that will save money and improve service to the public. The proposed research has the potential for significant payoff. The number and mix of spare buses at a transit agency can have major service quality and/or financial implications, whether the ratio is too "lean" or too "fat." There are significant capital and operating costs of acquiring and maintaining more buses that are necessary to support an agency's transit service complement, maintenance program, and other ancillary needs (training, marketing, special events, etc.). Conversely, inadequate numbers (and types) of spare vehicles can have adverse impacts on the transit services delivered to the public, which can be manifested in terms of missed trips, service interruptions, and vehicle condition. Furthermore, there may be implications to an agency receiving federal funding that exceeds the FTA 20% spare ratio guideline.

VII. RELATIONSHIP TO FTA STRATEGIC RESEARCH GOALS AND TCRP STRATEGIC PRIORITIES

Efficient fleet management with the optimal number of spare buses is not an end in itself. It is a key factor that can impact service quality and safety, fleet maintenance and asset preservation, and cost-effective operation.

As such, this proposed project relates directly to the FTA's Strategic Research Goal of:

- *Supporting the Improvement of the Performance of Transit Operations and Systems*, addressing the questions: How can we improve the reliability of our transit systems and the productivity of our transit workforce? What technical and operational advances best contribute to cost-effective management of the planning, design, construction, and operation of major transit investments? What technologies and practices are available to promote the most cost-effective service and capital replacement policies? How do we ensure transit assets are in a state of good repair? How can we systematically promote life-cycle planning for transit assets?

This proposed research also supports the TCRP Strategic Priorities of:

- *Placing the Transit Customer First* by supporting cost-effective bus fleets (with an optimal spare bus ratio) that meet transit service requirements with safe, clean, and dependable vehicles
- *Enabling Transit to Operate in a Technologically Advanced Society* by supporting the continued operation and maintenance of technologically advanced buses and their component systems—and their safety, comfort, convenience, and environmental benefits.
- *Revitalizing Transit Organizations* by providing transit agencies with tools to better manage their bus fleets through information technologies, changes in the work force, and new roles and partnerships to "Work Better—Cost Less."

VIII. RELATED STUDIES

The purpose of this synthesis, TCRP Synthesis Topic SA-32: *System-Specific Spare Bus Ratio Update*, is to update the findings of *TCRP Synthesis 11* (published in 1995), providing guidance to transit agencies on how various factors may affect optimal fleet size.

Other related past studies include:

- Li, T., A. Gan, and F. Cevallos, "Characteristics of Bus Transit Vehicles in the United States: How They Have Changed Over a Quarter Century," Presented at the 53rd Annual Transportation Research Forum, Tampa, Fla., Mar. 15–17, 2012.
- Schiavone, J., *Method and Processes for Transit Training Metrics and Return on Investment*, Transportation Learning Center, Silver Spring, Md., 2011.
- Minkoff, M., "Bus Fleet Management in an Era of Increasing Technical Complexity: Analysis of Bus Fleet Spare Ratios," TCRP Project J-06, Task 73, Transportation Research Board of the National Academies, Washington, D.C., 2009.

IX. PERSON(S) DEVELOPING THE PROBLEM

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(206) 801-2823; (206) 801-2899 (Fax); E-mail: martin.minkoff@icfi.com.

X. PROCESS USED TO DEVELOP PROBLEM STATEMENT

This problem statement was initiated at the request of, and developed with input from, the TCRP Synthesis Panel SA-32: *System-Specific Spare Ratio Update*—as part of the draft synthesis document review process.

XI. DATE AND SUBMITTED: Submitted by Martin Minkoff, ICF International, on behalf of the TCRP J-7 Synthesis Topic Panel (SA-32), June 13, 2013.

APPENDIX D

Compilation of Agency Survey Responses

Contact information for the “Compilation of Agency Survey Responses” is provided at www.trb.org, search on “TCRP Synthesis 109.”

Abbreviations used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation