Bus Fleet Management in an Era of Increasing Technical Complexity: Analysis of Bus Fleet Spare Ratios

FINAL REPORT

Requested by:
American Public Transportation Association
Bus Technical Maintenance Committee

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I. EXECUTIVE SUMMARY

For over 20 years, the 20% Spare Ratio policy has been applied to transit industry bus fleets with 50 or more vehicles. Federal Transit Administration (FTA) policy states that "Spare ratios will be taken into account in the review of projects to replace, rebuild, or add vehicles. "

FTA defines the spare ratio as "the number of spare vehicles divided by the vehicles required for annual maximum service. Spare ratio is usually expressed as a percentage, e.g., 100 vehicles required and 20 spare vehicles is a 20 percent spare ratio."

Over time, significant changes have taken place affecting bus fleet characteristics and management. These changes warrant an examination of how the spare bus ratio is defined and calculated, and how the 20% spare ratio is currently applied in the field.

Toward that end, this research project focused on six critical questions:

- Has increased fleet mix diversity impacted transit agencies and their ability to operate within a 20% spare ratio?

- Has the introduction of these new fuel/energy system technologies, along with the traditional motive power sources, impacted transit organizations and their ability to operate within a 20% spare ratio?

- Has the implementation of advanced on-board technology systems and equipment affected transit agencies and their ability to operate within a 20% spare ratio?

- Has the scope and nature of the service profile offered to the public, and the interchangeability limitations between subfleets, impacted transit systems in meeting their daily pull-out requirements while operating within a 20% fleet-wide spare ratio?

- Have workforce constraints and the expansion of advanced fuel/energy systems and on-board technologies significantly challenged maintenance programs in maintaining, servicing, and fueling their fleets?

- Is a 20% spare ratio an appropriate benchmark for the transit industry in managing its fleets?

Toward answering the critical questions posed above, significant data collection and research has been conducted, including the following:

- Analyzing the 2007 National Transit Database (NTD);
- Conducting and Analyzing a Comprehensive On-line Survey of Bus Transit Agencies;
- Preparing Three Case Studies of Survey Respondents; and
- Obtaining FTA Perspectives on the Spare Ratio Policy.

Based upon the research and analysis the following conclusions are provided for consideration *under the APTA Standards Program:*

1. **General items to consider in developing a recommended practice for calculation of spare bus ratios:**
   - Buses less than 35–feet in length may be excluded when calculating the spare ratio.
   - Buses with non-diesel propulsion systems may be excluded when calculating the spare ratio.
   - Buses being replaced by newly-procured buses may be excluded for a defined period of time when calculating the spare bus ratio.
   - Demand-responsive fleets, regardless of equipment used or fleet size, may be excluded when calculating the spare bus ratio.
   - Trolley bus fleets (powered by overhead electric catenary system) may be excluded when calculating the spare bus ratio.
   - Seasonal fleets may be excluded when calculating the spare bus ratio.
   - Specific fixed-route subfleets may be excluded when calculating the fleet-wide spare ratio, such as experimental vehicles being tested in revenue service.
   - Fleets designated as having manufacturer fleet defects may be excluded when calculating the spare bus ratio.
   - Buses operating in revenue service that have reached the end of their federally-defined minimum useful life may be excluded when calculating the spare ratio.
   - Buses not needed as a result of service cuts (for financial reasons) may be excluded when calculating the spare ratio, if those vehicles would be necessary to restore service when financial conditions improve.

2. **For fixed-route fleets with fewer than 50 revenue vehicles**: Due to the highly variable local context of small fleets, the appropriate spare ratio should be determined by the transit agency based on local conditions.

3. **For fixed-route fleets with 50 to 250 revenue vehicles:** The research indicates that agencies operating between 50 and 250 revenue vehicles may need the flexibility to maintain the spare ratio levels that best meets their unique needs and local conditions. To support the efficient utilization of capital and maintenance resources in the delivery of bus transit services and to inform internal management and funding agency decisions, it is suggested that agencies prepare an annual spare bus ratio report to include a narrative explanation describing the basis for spare bus needs and any extenuating factors.

4. **For fixed-route fleets with more than 250 revenue vehicles:** The research indicates that for agencies operating more than 250 revenue vehicles, a fleet-wide spare ratio of 25% may be a reasonable level, with the need for flexibility beyond that level in consideration of unique needs and local conditions. To support the efficient utilization of capital and maintenance resources in the delivery of bus transit services and to inform internal management and funding agency decisions, it is suggested that agencies prepare an annual spare bus ratio report. It is further suggested that agencies with spare bus ratios above 25% prepare a more extensive bus fleet management plan describing the basis for spare bus needs, extenuating factors, and efforts to optimize the number of spare buses.

The research and suggestions contained in this report are intended to assist APTA in the development of its bus standards and provide information to the transit industry in areas concerning bus fleet management in this era of increasing technical complexity.

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II. CONCLUSIONS

Following are conclusions regarding bus spare ratios that are based upon the data and analysis described in this report. They are intended for use by APTA and the transit industry to aid in the development of industry standards (under the APTA Standards Development Program).

Clearly, all public transit agencies have a strong interest in finding the "right" number of spare vehicles required to meet daily service needs, perform necessary maintenance and repair requirements, and accomplish regular fueling, servicing, and cleaning. That "right" number is a balance between fiduciary responsibilities, proper asset management, efficient operational and maintenance practices, and the challenges of delivering high quality services to a growing ridership base. Carrying more spare buses than absolutely needed is an unnecessary capital and operating expense.

Based upon the research and analysis the following conclusions are provided for consideration *under the APTA Standards Program:*

1. General items to consider in developing a recommended practice for calculation of spare bus ratios:

- Buses less than 35–feet in length may be excluded when calculating the spare ratio.
- Buses with non-diesel propulsion systems may be excluded when calculating the spare ratio.
- Buses being replaced by newly-procured buses may be excluded for a defined period of time when calculating the spare bus ratio.
- Demand-responsive fleets, regardless of equipment used or fleet size, may be excluded when calculating the spare bus ratio.
- Trolley bus fleets (powered by overhead electric catenary system) may be excluded when calculating the spare bus ratio.
- Seasonal fleets may be excluded when calculating the spare bus ratio.
- Specific fixed-route subfleets may be excluded when calculating the fleet-wide spare ratio, such as experimental vehicles being tested in revenue service.
- Fleets designated as having manufacturer fleet defects may be excluded when calculating the spare bus ratio.
- Buses operating in revenue service that have reached the end of their federally-defined minimum useful life may be excluded when calculating the spare ratio.
- Buses not needed as a result of service cuts (for financial reasons) may be excluded when calculating the spare ratio, if those vehicles would be necessary to restore service when financial conditions improve.

2. **For fixed-route fleets with fewer than 50 revenue vehicles**: Due to the highly variable local context of small fleets, the appropriate spare ratio should be determined by the transit agency based on local conditions.

3. **For fixed-route fleets with 50 to 250 revenue vehicles:** The research indicates that agencies operating between 50 and 250 revenue vehicles may need the flexibility to maintain the spare ratio levels that best meets their unique needs and local conditions. To support the efficient utilization of capital and maintenance resources in the delivery of bus transit services and to inform internal management and funding agency decisions, it is suggested that agencies prepare an annual spare bus ratio report to include a narrative explanation describing the basis for spare bus needs and any extenuating factors.

4. **For fixed-route fleets with more than 250 revenue vehicles:** The research indicates that for agencies operating more than 250 revenue vehicles, a fleet-wide spare ratio of 25% may be a reasonable level, with the need for flexibility beyond that level in consideration of unique needs and local conditions. To support the efficient utilization of capital and maintenance resources in the delivery of bus transit services and to inform internal management and funding agency decisions, it is suggested that agencies prepare an annual spare bus ratio report. It is further suggested that agencies with spare bus ratios above 25% prepare a more extensive bus fleet management plan describing the basis for spare bus needs, extenuating factors, and efforts to optimize the number of spare buses.

The research and conclusions contained in this report are intended to assist APTA in the development of its bus standards and provide information to the transit industry in areas concerning bus fleet management in this era of increasing technical complexity.

ADDITIONAL RESEARCH

The following additional research is recommended toward assisting in determining appropriate fleet sizes, given local transit system conditions and characteristics:

- *Analysis of Time Required for Fueling and Servicing Alternatively-Fueled Buses (e.g. CNG, LNG, etc.) and Identification of Process Improvements.*
- *Best Practices of Bus Transit Agencies in the Coordination of Maintenance, Operations, and Service Planning.*
- *Analysis of the Impact of Current and Future Diesel Exhaust Emission Standards (e.g., Federal Diesel Emission Reduction Act) on Bus Fleet Maintenance Programs.*
- *Analysis of the Relationship between Bus Fleet Age, Bus Mileage, Reliability, Operating Cost, and Maintenance Requirements.*

III. PROBLEM DEFINITION

1. Applicable Policy

For over 20 years, the 20% Spare Ratio policy has been applied to transit industry bus fleets with 50 or more vehicles. Federal Transit Administration (FTA) policy states that "Spare ratios will be taken into account in the review of projects to replace, rebuild, or add vehicles. "

For bus fleets, "the basis for determining a reasonable spare ratio takes local circumstances into account. The number of spare buses in the active fleet for grantees operating 50 or more fixed-route revenue vehicles should not exceed 20 percent of the number of vehicles operated in maximum fixed-route service."

FTA defines the spare ratio as "the number of spare vehicles divided by the vehicles required for annual maximum service. Spare ratio is usually expressed as a percentage, e.g., 100 vehicles required and 20 spare vehicles is a 20 percent 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)

Transit agency compliance with the policy is assessed by the FTA through both the grant request process for new buses and the FTA Triennial Review Process. The Triennial review follows the process delineated in the FTA Triennial Review Workbook.

Relevant language from both Circulars C5010.1D and C9030.1C and the *FY 09 FTA Triennial Review Workbook* is contained in Appendix A.

2. Changes and Challenges

Over time, significant changes have taken place affecting bus fleet characteristics and management. These changes clearly warrant a reexamination of the 20% spare ratio. Following are some of the major categories of change:

a. FLEET MIX DIVERSITY: Transit bus fleets have become increasingly diverse in terms of vehicle types. Fleets which historically operated 35-foot and/or 40-foot standard buses exclusively, now operate a wide mix of vehicle size, passenger carrying capacity, and configurations.

b. FUEL/ENERGY SYSTEM TECHNOLOGIES: Transit fleets have introduced various new fuel and energy technologies that involve more complex maintenance issues and require more time to maintain, service, and, in some cases, fuel (e.g., hybrid-electric, advanced diesel, fuel cell, CNG, LNG, etc.).

c. ADVANCED ON-BOARD TECHNOLOGY SYSTEMS: Transit fleets have also introduced advanced technology equipment and ancillary components on-board the vehicle that also involve more complex maintenance issues and take more time to maintain (e.g., advanced emission controls, electronic fare collection, digital communications systems, video surveillance, automatic vehicle location, and automatic passenger counter technology, etc.).

d. SERVICE PROFILE: Transit fleets have been called upon to support a wide range of service types and initiatives. Many of these services have specific requirements that cannot be met by all buses in the fleet, thus limiting interchangeability.

e. MAINTENANCE PROGRAMS: During this same period, transit systems have faced many challenges in ensuring that their maintenance workforces have the skills to maintain, diagnose, and repair diverse and technologically advanced bus fleets.

3. Non-Fixed-Route Spare Ratio Areas

The following Non-Fixed Route Bus Fleet Spare Ratio areas will not be substantively addressed in this study, as explained below.

a. DEMAND-RESPONSIVE BUS FLEETS: There is some ambiguity as to whether or not the Bus Spare Ratios apply to Demand-Responsive fleets (with more than 50 vehicles). Demand-responsive fleets have limited diversity in fleet type (i.e., predominantly consisting of vehicles less than 30-feet in length with gasoline or diesel fueling). Also, given the variability in daily demand and the requirement to accommodate **all** ADA trip requests, it is difficult to consistently determine the number of vehicles operated in maximum service (and calculate an accurate spare ratio). For these reasons, the research will focus on Fixed-Route bus spare ratios only.

b. TROLLEY BUS FLEETS: Rubber-tired trolley buses, electrically powered via an overhead catenary system, are operated by four U.S. transit systems in Boston, Dayton, San Francisco, and Seattle. It is understood that although they operate on "fixed-routes," trolley bus fleets are treated as rail vehicle fleets (see below) for purposes of the Spare Ratio. As such, trolley buses will be referenced peripherally in this project.

c. RAIL VEHICLE FLEETS: Given the diversity and variety of rail vehicle fleets, there is not a defined spare ratio (e.g., 20%); there is, however, a requirement for a Rail Fleet Management Plan that provides the rationale and justification for an agency's rail vehicle fleet spare ratio(s). Rail fleet spare ratios will not be addressed in this project.

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IV. PRIMARY OBJECTIVES AND CRITICAL QUESTIONS

The primary objectives of this project are to:

- assess the effects of the changing conditions and challenges, described above, on transit industry bus fleet requirements, and

- develop recommendations for consideration by the American Public Transportation Association (APTA) to include in the APTA standards development process, and to inform the transit industry concerning fleet management issues.

Toward accomplishing these objectives, there are six critical questions that the research focused on:

1. Has increased fleet mix diversity impacted transit agencies and their ability to operate within a 20% spare ratio?

2. Has the introduction of new fuel/energy system technologies, along with the traditional motive power sources, impacted transit organizations and their ability to operate within a 20% spare ratio?

3. Has the implementation of advanced on-board technology systems and equipment affected transit agencies and their ability to operate within a 20% spare ratio?

4. Has the scope and nature of the service profile offered to the public, and the interchangeability limitations between subfleets, impacted transit systems in meeting their daily pull-out requirements while operating within a 20% fleet-wide spare ratio?

5. Have workforce constraints and the expansion of advanced fuel/energy systems and on-board technologies significantly challenged maintenance programs in maintaining, servicing, and fueling their fleets?

6. Is a 20% spare ratio appropriate as a benchmark for the transit industry?

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V. DATA COLLECTION AND RESEARCH

Toward answering the critical questions posed above, significant data collection and research has been conducted, including the following:

A. NATIONAL TRANSIT DATABASE (NTD) ANALYSIS

The research drew heavily on the 2007 National Transit Data Base for aggregate data provided by transit agencies that participate in the NTD program. The 2007 Data Tables were downloaded and analyzed in Excel spreadsheets. Appendix B contains more information on the data collected and analyzed.

B. ON-LINE SURVEY

The project supplemented the 2007 National Transit Database with a comprehensive, detailed, web-based survey of U.S. and Canadian bus agencies. This enabled a wealth of quantitative and anecdotal information to be gathered at the fleet-wide and subfleet levels. Appendix B contains more information on the survey plan and instrument.

The link to the comprehensive, on-line survey instrument was e-mailed to approximately 400 APTA member agencies, with a 45-day response period.

Following is a profile of the respondents to the survey:

- 129 Complete Agency Responses (an approximate response rate of 30%)
- 26 Partial Agency Responses
- 113 Agencies with Directly-Operated (DO) Fleets
- 33 Agencies with Purchased Transportation (PT) Fleets
- 17 Agencies with both Directly Operated and Purchased Transportation Fleets
- 107 U.S. Agencies with National Transit Database (NTD) Entries
- 16 U.S. Agencies without NTD Entries
- 6 Canadian Agencies (non-NTD Participants)

The survey sample represents the tremendous variation among responding agencies in terms of Service Area, Ridership, and Operational and Fleet Characteristics. It is reasonable to infer that the highly diverse "population" of transit agencies in the U.S. and Canada is appropriately represented by the survey sample.

C. CASE STUDIES

Three case studies have been prepared based upon telephone interviews with selected on-line survey respondents. The case studies are intended to complement the on-line survey analysis to provide some "real-world" illustrative examples of how the spare ratio issue affects a small, medium, and large transit property's bus fleet management. The interview questions were based upon the critical questions listed above.

The three case study participants are:

- City of Culver City Transit, Culver City, CA (Small Property)
- Niagara Frontier Transportation Authority, Buffalo, NY (Medium Property)
- City of Phoenix, Public Transit Dept., Phoenix, AZ (Large Property)

Each case study is summarized in Appendix D.

D. FTA PERSPECTIVES

As well, information has been obtained from the FTA concerning their perspectives on the bus fleet spare ratio policy. This information is contained in Appendix E.

VI. KEY FINDINGS

Following are the key findings drawn from the research and analysis. Each is described in support of answering the six "Critical Questions" identified above in *Section IV*. For more detail on the analysis supporting these and other findings, please refer to Appendix C.

1. Has increased fleet mix diversity impacted transit agencies and their ability to operate within a 20% spare ratio?

Yes. Increased fleet mix diversity has impacted many transit agencies and their ability to operate within a 20% spare ratio.

The survey research found that U.S. and Canadian transit agencies collectively maintained within their bus fleets, 15 different bus "subfleet" categories. The subfleets are defined as a group of vehicles within the fleet that have common size and vehicle type attributes. The 15 primary subfleets found in the survey are:

Less than 30-foot Bus	30-foot Bus	35-foot Standard Bus
40-foot Standard Bus	60-foot Std. Articulated Bus	Over-the-Road (3-Axle) Bus
40-"Suburban" Bus (2-Axle)	45-foot Bus (2-Axle)	Rubber-Tired Trolley Replica
40-BRT Bus	Double-Decker Bus	35-foot Mountain Grade Bus
60-foot BRT Articulated Bus	40-foot Electric Trolley Bus	60-foot Electric Trolley Bus

The responding transit agencies had, on average, 3.1 different subfleets within their *directly operated*, fixed-route fleet, and 2.6 different subfleets in their *purchased transportation* fleet. The variance within each distribution is quite wide, with half of the 113 *directly-operated* fleets having more than 3 subfleets, and half having fewer than 3. The largest number of subfleets reported by an agency was 8 and the smallest number was 1. *Purchased transportation* fleets had a lower median, with half of the 33 fleets having more than 2 subfleets and half having fewer than 2.

With the increased diversity of subfleets often comes variable spare bus needs within each subfleet. Where an agency has one or more subfleets that exceed 20%, it must reduce the number of spare buses below 20% in the agency's other subfleets in order to come in below a 20% spare ratio. In many cases this is not feasible without adverse maintenance, operational, or service quality implications.

In further analyzing the survey data, there are significant numbers of agency fleets that have subfleets exceeding a 20% spare ratio. *This is most acute in the "30-foot Bus" and "Less-than-30-foot Bus" subfleet categories,* however, there are also a large number of 35-foot, 40-foot, and 60-foot articulated bus subfleets that exceed 20%. Following are the most noteworthy examples of the very high percentages of *directly-operated* subfleets that are in excess of 20%:

- For all 43 reported *Less-than-30-foot Bus* subfleets, 37% had a spare ratio that was less than or equal to 20%, however 63% had spare ratios that exceeded 20%--with 44% having subfleet spare ratios exceeding 30%.

- For all 65 reported *30-foot Bus* subfleets, 45% had a spare ratio that was less than or equal to 20%, however 55% had spare ratios that exceeded 20%--with 46% having subfleet spare ratios exceeding 30%.

- For all 63 reported *35-foot Bus* subfleets, 56% had a spare ratio that was less than or equal to 20%, however 44% had spare ratios that exceeded 20%--with 22% having subfleet spare ratios exceeding 30%.

- For all 88 reported *40-foot Standard Bus* subfleets, 56% had a spare ratio that was less than or equal to 20%, however 44% had spare ratios that exceeded 20%--with 10% having subfleet spare ratios exceeding 30%.

- For all 28 reported *60-foot Standard Articulated Bus* subfleets, 57% had a spare ratio that was less than or equal to 20%, however 43% had spare ratios that exceeded 20%--with 14% having subfleet spare ratios exceeding 30%.

There are similar examples among the surveyed *purchased transportation* fleets and subfleets.

Following are a range of comments from survey respondents:

> *"Because of the technical and operational reasons mentioned, our 40-foot bus fleet is also over the allowable 20% spare ratio rule. Since we only have six 30-foot buses, if there are not enough buses to meet the daily requirement, we would deploy 40-foot buses to meet the operational requirement. This in turn lowers available spares (on 40-foot buses) for that day's commitment."*

"Given this subfleet quantity is calculated in the overall spare ratio, for every one of these buses on hand over the 20% spare ratio, it reduces on a one for one basis the number of spare 40' buses we can have on hand and available for service. Looking at peak requirements of 11 (smaller buses) vs. 183 (40' buses) the offset is extremely disproportionate and adversely impacts our support of the larger fleet's revenue service requirements."

"No (problem achieving the 20% guideline) because we currently only operate 30-foot and 40-foot buses. Future plans for growth and different types of buses to meet passenger and services demands will constitute the purchase of 60-foot articulated buses in the fleet. They will also need to have a spare ratio conducive to the technology and operational demands. Branding buses differently to meet BRT obligations further exacerbate the spare ratio problems as you need spare buses for this "second" fleet of equipment."

2. Has the introduction of new fuel/energy system technologies, along with the traditional motive power sources, impacted transit organizations and their ability to operate within a 20% spare ratio?

Yes. The introduction of a broader range of fuel and propulsion technologies appears to have impacted many transit agencies and their ability to maintain their spare bus levels at 20%.

The increasing prevalence, diversity, and complexity of today's fuel/energy systems has had a clear impact on agency spare bus needs. While not the case for every transit organization, for many agencies this complexity appears to challenge their ability to maintain a 20% overall fleet spare ratio.

Based upon 101 responses to this survey question, the average *directly-operated* bus fleet has nearly two (1.8) fuel/energy systems to manage in its daily maintenance and operation. The median number of fuel/energy systems is 2.0, meaning 50% of all *directly-operated* bus fleets have more than 2 fuel/energy systems (as many as 5), and 50% have fewer than 2 (and as few as 1). Add into this the number of fuel/energy system subfleets (accounting for different bus sizes and fueling type) and the average goes up to 3.5 with a median of 4. The number of fuel/energy system subfleets were reported as high as 8 and as few as 1. The 28 *purchased transportation* fleet responses to this question had very similar results.

The survey clearly points to the continued dominance of *diesel* as a bus propulsion system; 99% of agencies with *directly-operated* fleets indicated that they operated *diesel* buses. Diesel accounted for 77% of all directly-operated buses reported in the survey. It should be noted, however, that the "Clean Diesel" engines of today are significantly more technologically complex than those of 20-plus years ago. *Hybrid-Electric (diesel)* buses were reported by 35% of these agencies (with 6% of the buses). *Compressed Natural Gas (CNG)* was listed in 20% of the *directly-operated* fleets (with 15% of the buses). *Purchased transportation* fleets were also dominated by *diesel*, followed by CNG.

Despite the dominance of *diesel*, the survey results reflected a wide array of other fuel/energy technologies in transit fleets. Many of those systems are not nearly as reliable as *diesel*, although they had been purchased for other reasons such as environmental benefits (both voluntarily and in response to regulatory mandates).

The fuel/energy system survey data clearly demonstrates the significant complexity that transit systems in the US and Canada deal with in their fleet maintenance and spare bus management.

Below are some illustrative comments from survey respondents:

"Occasionally these buses require extensive maintenance because of the complicated and technical requirements of the fuel system (CNG) and engine. Parts for these engines (and fuel system) are expensive and can prevent these vehicles from entering service due to the length of time it sometimes takes for specific parts. As stated, over the last twenty years the "transit bus" has tremendously evolved and currently, modern-day technically advanced buses are considered one of the most highly advanced operational-technical equipment on the road. They are complex, house many sub-systems inherent to providing public transit vehicle services that is safe and reliable. The various complexities add to down times, with parts attainment and advanced repair procedures adding to the duty cycle of the vehicle."

"(We) have 62 gasoline hybrid coaches that are new technology and are unreliable. An old technology diesel coach has standard 90 - 92% reliability, while a gasoline hybrid has less than 80% reliability (counting all unplanned work). The majority of the difference has to do with the propulsion system (inverters, ultracapacitors, engines, PLC system etc...). These coaches are relatively new (3.2 years) and they are having tons of problems. In the past, a new diesel had hardly any failures during the first 4 years of life. Note: the newer diesels (starting with 2003) with the upgraded emission systems are starting to have lower reliability."

"These 30 hybrid coaches have been experiencing an abnormal number of failures i.e. fuel transfer pumps, traction batteries, air compressors, door sensors, etc. While there is warranty support, the coaches are still required to be removed from service while this repair activity takes place. These fleet defects have also been detrimental to vehicle reliability in this fleet; these critical systems have failed with such regularity as to cause repeated road calls and a resultant decrease in MDBF. Long lead times, increased demand from the parts manufacturer with no alternate vendors available means a higher spare ratio is needed just to be sure we can put the correct number of coaches into the field each day. Without a spare ratio higher than the normal 20%, maintenance and passenger service would suffer."

3. Has the implementation of advanced on-board technology systems and equipment affected transit agencies and their ability to operate within a 20% spare ratio?

Yes. The implementation of these advanced systems has impacted many transit agencies and their ability to adhere to a 20% spare ratio.

Complex, advanced technology systems have become increasingly commonplace on-board transit vehicles at both large and small properties. On average, the 129 responding agencies reported having over 6 advanced technology systems (6.4) with a median of 6.0; one-half of all responding agencies support more than 6 Advanced Technologies and one-half support fewer than 6. The largest number of advanced technologies at a single agency was 12, with lowest number being 1.

Over 50% of the agencies reported having each of the following complex technologies to support:

- Electronic Head Signs
- On-Board Video Surveillance
- Electronic Fare Collection
- Digital Radio
- Automatic Vehicle Locator
- Advanced Emission Controls
- Bus Stop Enunciation

When asked how these advanced technologies impacted their ability to stay at or below the 20% spare ratio level, 60% of the survey respondents indicated that the introduction of advanced technology systems at their agencies did **not** affect their ability to maintain a 20% spare ratio. However, over one-third of the responding organizations (38%) did express that these systems affected their ability to keep the entire active fleet within the 20% spare ratio level.

Following are some illustrative comments from survey respondents:

> "*New technology buses have multiple electronic subsystems like CAD/AVL, vehicle health monitoring, cameras, automated fueling, ECT. We have also added emission devices and other environmental designed subcomponents. Years ago when the spare ratio was created no specialized electronics or emissions systems were part of bus design and maintenance. The addition of this equipment has burdened the labor resources and facility design to the point where it is very difficult to maintain service requirements.*"

"These sub-systems are now required to keep a coach in service and are very technical - thus requiring specialized technicians to repair them. Many times one system will cause a problem with another (for example, interference of one wireless system (GPS) with another wireless video surveillance system)."

"Each additional item of technology that is added to a vehicle is another item that must be maintained and repaired - thus increasing maintenance time required and therefore reducing vehicle availability, which impacts our ability to support revenue service requirements within the 20% cap."

"With all these enhancements to these coaches there comes an increased level of maintenance and associated cost. Coaches must be kept out of service routinely for vendor maintenance, adjustment or programming. This means added handling, increased storage needs, scheduling, etc. While these systems are in for maintenance other coaches must be use to backfill for them on the line; these new systems' maintenance needs are not factored into any spare ratio calculations, as that has not changed from before these systems came into existence."

Even the predominant "Clean Diesel" technology of today relies on complex emission control systems.

"Some of the advanced technology has proven to be more problematic than it's worth. The advanced emission controls have increased maintenance demands and road call service interruptions. The need to perform frequent engine exhaust regenerations manually cost countless man-hours and equipment to keep vehicles on the road. The original design was for the regenerations to be automatic and virtually invisible to the operator and maintenance. The 20 percent spare ratio in this case is inadequate to keep the line at the desired supply without additional buses. Most other technology items have not been a problem or are not critical and can be worked around."

As with the fuel/energy systems discussed above, the complexity and prevalence of today's advanced technology systems also has a strong impact on agency spare bus requirements. While not the case for every transit organization, for many agencies the introduction of advanced technology systems and their complexities has challenged their ability to operate within a 20% spare ratio.

4. Has the scope and nature of the service profile offered to the public, and the interchangeability limitations between subfleets, impacted transit systems in meeting their daily pull-out requirements while operating within a 20% fleet-wide spare ratio?

For some. For a significant minority (24% of those responding to the survey question), the service mix and interchangeability limitations between subfleets has impacted their ability to meet daily pull-out requirements. The majority (76% of those responding to the survey question) have not found this be an issue of concern.

U.S. and Canadian transit systems deliver a wide range and diverse mix of services to the public. Local Route service is the clearly the predominant service type, offered by 96% of the surveyed respondents. However, between 43% and 51 % of surveyed agencies also provide Commuter Express, Emergency, Circulator, Shuttle, and Special Event services. Continuing to emerge as a cost-effective, high-capacity transit solution, Bus Rapid Transit (BRT) service is offered by 16% of those agencies responding to the survey.

Each transit organization, on average, provides about 4 different types of service. With a median of 4.0: one-half of all agencies offer more than 4 service types and one-half provide fewer. The largest number of service types reported by an agency was 10, with the smallest number being 1.

Each service type has its own unique operating characteristics, maintenance demands, and, in many case, specialized vehicle and accessory requirements. Consequently, to fully meet the needs of the range of service types offered by each agency, the spare ratio must be sufficient within the subfleet(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. Following are some of the major requirements that can govern and limit the interchangeable use of certain spare buses.

The survey found that in order to deliver Bus Rapid Transit service, a bus assigned to that service MUST have the following specialized features:

- Low-Floor (reported by 80% of respondents that offer that service)
- Special Exterior Branding with Unique Paint (or Wrap) Scheme (by 70%)
- More than One-Door (by 65%)
- High-Passenger Carrying Capacity (by 60%)
- Premium Seating and Other Interior Amenities (by 55%)

The survey found that in order to deliver ***Commuter Express*** service, a bus assigned to that service MUST have the following specialized features:

- Premium Seating and Other Interior Amenities (reported by 50% of respondents that offer that service)
- High-Passenger Carrying Capacity (by 42%)
- More than One-Door (by 38%)
- Luggage Racks and Storage (by 32%)

The survey found that in order to deliver ***Regional Trunk*** service, a bus assigned to that service MUST have the following specialized features:

- More than One-Door (reported by 41% of respondents that offer that service)
- Low-Floor (by 38%)
- Premium Seating and Other Interior Amenities (by 28%)

The survey found that in order to deliver ***Local Route*** service, a bus assigned to that service MUST have the following specialized features:

- More than One-Door (reported by 56% of respondents that offer that service)
- Low-Floor (by 52%)
- Ability to Maneuver in Confined Areas (by 39%)

The survey found that in order to deliver ***Circulator*** service, a bus assigned to that service MUST have the following specialized features:

- Ability to Maneuver in Confined Areas (reported by 57% of respondents that offer that service)
- Low-Floor (by 41%)
- More than One-Door (by 39%)
- Special Exterior Branding with Unique Paint (or Wrap) Scheme (by 27%)

The survey found that in order to deliver ***Shuttle*** service, a bus assigned to that service MUST have the following specialized features:

- Ability to Maneuver in Confined Areas (reported by 46% of respondents that offer that service)
- More than One-Door (by 45%)
- Low-Floor (by 36%)
- Special Exterior Branding with Unique Paint (or Wrap) Scheme (by 30%)

As noted above, of the 89 responding to the question, "*Has the lack of available buses equipped with these essential Specialized Features affected your ability to meet daily pull-out requirements of any of your services?,"* 76% indicated "NO," and 24% reported "YES." The lack of having the "right" bus available to meet their specific service needs does not appear to be a problem for three-quarters of those agencies responding to the question. Conversely, the lack of having the appropriate bus available *does* impact the ability of one-quarter of the respondents to meet their daily pull-out requirements--though a minority, still a significant proportion.

Following are some comments from those survey respondents that indicated "YES" on the question above:

> *"HVAC is required to be operable on every bus placed into passenger service. Buses with non-functioning air conditioning are not placed into service or removed from service and replaced if possible during the months of April through November. Air conditioning during the period noted above is an employee/passenger life safety requirement. We're in Arizona...high temperatures can reach 115 degrees."*
>
> *"Occasionally it is a problem."*
>
> *"The special branded shuttle buses. They are a problem bus to begin with - very unreliable. We have to have extras in each brand type to insure the number needed for their peak requirement."*
>
> *"Even with a spare ratio exceeding 20% for the BRT Fleet, it has been a challenge to maintain a minimum of 10 buses available for peak schedule requirements. These buses have special branding and are not used on traditional local routes."*
>
> *"With our circulator service in the downtown, if a 30' coach is not available, we miss service. We cannot substitute our 30' coaches with any other coaches."*
>
> *"When 60' buses not available, substituting 40' buses reduces capacity."*

5. Have workforce constraints and the expansion of advanced fuel/energy systems and on-board technologies significantly challenged maintenance programs in maintaining, servicing, and fueling their fleets?

Yes. Overall, the transit industry has a very serious problem in attracting, retaining, and training sufficient numbers of mechanics and technicians that are able to maintain and repair today's technologically complex transit fleets and the myriad of systems and sub-systems. While some agencies are better able to meet these challenges than others, the impacts are ultimately manifested in the time period it takes to inspect, diagnose, and repair a bus that has come in for component failure or preventive maintenance. The longer this time period takes, the longer the bus is down and an appropriate spare bus needed to replace it in revenue service. This is the nexus with the spare ratio. The enormous challenges facing Bus Fleet Maintenance programs are clearly straining the spare bus fleet for many agencies as they struggle to ensure that the sufficient number and types of buses are available to protect daily revenue service.

For all survey respondents answering the questions, the total Net Difference between the number of mechanics and technicians **required** to support the fleets and the number **budgeted** is minus-120; 73% of the responding agencies indicated that they are not in need of additional budgeted positions and 21% of the agencies reported that they do not need additional budgeted positions. The largest net budgeted need of mechanics/technician positions at a single agency is a deficit of 32 slots.

At first glance, this does not appear to indicate a serious problem. However, even though a position is budgeted, it does not mean that it is filled. The essay responses to the survey question: "What*, if any, challenges has your organization experienced in Attracting, Retaining, and Training qualified mechanics/technicians*?" are particularly noteworthy. While some agencies indicated that they had no problems at this time, the bulk of respondents expressed numerous challenges and concerns.

The most significant challenges emerging from the survey are:

Finding Experienced Mechanics: In several local labor markets, there is a limited-to-non-existent pool of mechanic/technician applicants that are sufficiently qualified and experienced to handle the technological proficiency requirements of the transit agency's fueling/energy systems and on-board advanced technologies.

Insufficient Pay: The pay scale and/or pay progression offered is not sufficient to attract and retain qualified mechanics/technicians relative to other competing organizations and industries.

Bad Hours/Days/ Job Progression: The hours, work days, and job progression discourages otherwise qualified applicants from seeking work (or staying with the transit agency). Under labor agreements, newly entering or low seniority employees frequently have to work graveyard shift and weekends; similar work at other work places (e.g., truck repair) may offer better work schedules to the less senior employee. As well, some contracts require a job progression starting at Service/Cleaner positions before advancing on to Technician or Journeyman Mechanic. This discourages many qualified individuals from applying.

Training Issues: Many issues are faced by transit agencies who develop and support their own mechanic/maintenance training programs, including the difficulties in keeping up with the latest technology, having sufficient funding to keep the programs going at a high-quality level; and making the employees available for the hours required for training (pulling them away from their much needed shop work).

While some agencies indicated that the recent economic downturn has somewhat improved the ability to attract new mechanics, the technical demands remain as well as the ever-diminishing funding available for critical training programs.

Toward meeting the rigorous demands of maintaining their agency's bus fleets and meeting the daily service pull-out requirements, nearly two-thirds (62%) of transit organizations surveyed operate three or more maintenance shifts.

Compounding the staffing challenges in bus maintenance departments are the numerous replacement parts, components, and systems requiring extraordinarily long lead times to procure. Many of these are specialized items required for the advanced fuel/energy systems and on-board technology systems. While prudent inventory planning and management can anticipate the need and stock levels for many items, others must be secured as parts and components actually fail. If such a part or component is required to safely and reliably keep the bus in service, the result is increased down time and the need for spare bus coverage to maintain revenue service.

Following are some comments from survey respondents that capture the essence of many of the maintenance program challenges:

> *"Finding qualified technicians with previous CNG experience is the most significant challenge. This challenge is mitigated with our training program that is designed to bring new technicians up to speed quickly."*

> *"The industry is suffering from major shortfalls in journeymen technicians who can repair advanced technology systems. Every property across the US is experiencing shortages in qualified technicians who possess the vast experience required of these advanced technological systems. This has created new strategies in the hiring, training and retention of employees. Many transit properties train and "breed" their own technicians thereby providing advanced technical instruction and bringing these employees forward as they gain valuable and necessary experience. The shortfall in qualified journeyman technicians creates maintenance repair problems to properly and effectively maintain these assets. As continual changes in technology advance, the capacity to hire experienced employees in the future is austere, and it will definitely impact the ability to provide reliable vehicles which must meet the ever-changing operational requirements. This is considered another strong reason for changing the spare ratio away from "20%."*

> *"This is a huge problem. Mechanics/Technicians now need both to get dirty wrench-turning, but also have to be computer literate. It used to be you learned fairly quickly on the job. The learning curve is much longer. We have had our own apprentice program to help solve the problem but it is a continuing challenge to find or grow good Technicians. Many people don't want to work a second or third shift. Many don't like the Union seniority system which limits what work they do in their early years on the job. We have to provide a lot more training which in turn takes mechanics/technicians away from their repair work. Every time we get a new bus there is a huge training requirement."*

> *"Training technicians to learn new technology is the biggest challenge. Most of our older mechanics are used to mechanical system and have no incentives to learn the new technology. Today we have to teach computers for diagnostics and electronics. The old days of replacing parts is gone. Our second major issue has to do with the lack of material and standard procedures for new technology. Most technology is sold on what it can do for us and the maintenance (being new technology) is an unknown. We all know that technology changes fast, but we have to keep everything operational for the minimum life of the coach (12 years). One last issue has to do with recruitment of new technicians. If you hire in new techs with electronic skills, they don't want to stay long because of the heavy-duty nature of the work. It is dirty and hard. Least senior mechanic has to do the heavy grunt work. If you hire an old skilled mechanic, they are not able to do any technical work."*

"This is a small fleet. 20% of a small fleet number is a small number as well. Given the number of miles operated and the fact that QUALITY service requires quality maintenance and time is required for doing that, a larger percentage of this small fleet number is required. Maintaining a productive and organized flow of work in maintenance is directly affected by the availability of buses to cover downtime. Further, weather extremes experienced in this part of the country frequently create issues with fleet availability due to increased need for trippers or to cover for buses mired in traffic or snow. Small spare numbers do not effectively accommodate these needs."

6. Is a 20% spare ratio appropriate as a benchmark for the transit industry?

This study concludes that a 20% spare ratio is not uniformly appropriate for the transit industry. In examining the 2007 NTD data presented in Appendix C, the following conclusions can be drawn:

- The average spare ratios, for the "50 or more bus fleets," of 24.7% and 24.6% (*Direct Operation and Purchased Transportation,* respectively) are approximately 5% higher than 20%.

- Those "50 or more bus" fleets have a significantly lower average spare ratio than the "fewer than 50 bus" fleets.

- There appears to be little difference between the average spare ratios of *Directly-Operated* and *Purchased Transportation* fleets within each of the two fleet size categories.

In further looking at the 157 fixed-route, *directly-operated* bus fleets with 50 or more vehicles, the spare ratios widely range from a low of 1.5% to a high of 65.9 percent. Similarly, the range of spare ratios for the 46 counterpart *purchased-transportation* fleets range from 4.1% to 48.8 percent. The high ends of both ranges are significantly above a 20% spare ratio.

Over time, agency spare ratios (as reported in the National Transit Database) have increased significantly since 1990 in both the 250-499 and 500-999 Vehicles Operated in Maximum Service (VOMS) fleet categories. In 2007, the mean spare ratio for the 250-499 VOMS category was 24.4%; and for the 500-999 bus fleets it was 25.7%. This represents an increase in the mean of 5.0% and 6.2% respectively, from 1990.

Although decreasing from 1990 in the 50-99 and 100-249 VOMS categories, the 2007 averages are still above a 20% spare ratio by 5.3% above and by 2.2% above, respectively. For the nation's largest bus fleets in the "1000 or more" VOMS category, there is a moderate downward change in the average spare ratio from 1990. This fleet category is the only one whose actual average spare ratio (18.1% in 2007) is below 20%.

Use of the Spare Ratio itself implicitly relies on the assumption that an agency's Vehicles Operated in Maximum Service (VOMS) is directly related to the number of spare buses they should need. In fact, this analysis found that the relationship between Vehicles Operated in Maximum Service (VOMS) and the number of Spare Buses is very weak in fleets up to 250 buses, with some limited additional strength shown when including fleets up to 499 vehicles. However, it appears that VOMS could be a very strong indicator for a larger fleet's (with 250 buses or more) spare bus requirements. Although testing several possible variable and fleet size combinations for potential correlation, this analysis could not identify a stronger alternative variable for small to mid-sized bus fleets (between 0 and 500 buses) that may be a better indicator of Spare Bus needs than VOMS.

VII. CONCLUSION

Based upon the research of the six critical questions listed above, this analysis has concluded that there have been significant changes in bus technology, fleet diversity, and the scope of transit services provided to the public. As well, there is tremendous variability among the transit systems in the U.S. and Canada in terms of their size, fleet characteristics, operating conditions, and maintenance staffing capabilities.

Agencies have been diligent and creative in meeting their maintenance and service requirements within their spare bus limitations. Still, when it comes to spare bus needs, one ratio clearly does not fit all. Any future APTA standards should reflect the need for flexibility, as well as accountability for the public investment in agency transit fleets.

Fourteen years ago, the 1995 publication of TCRP Synthesis 11, *System Specific Spare Bus Ratios*, by Judith Pierce and Elizabeth Moser (2), stated the following:

> *"Although transit managers generally acknowledged that right-sizing the fleet actually improves operations and lowers costs, many reported difficulties in achieving and consistently maintaining a 20 percent spare ratio as recommended by FTA. The general 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 property."*

This additional flexibility continues to be warranted, particularly in this current era of increasing technological complexity. The research contained in this report forms a strong basis for revisiting and considering alternative approaches to spare ratios.

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VIII. APPENDIXES

A. Synopsis of Applicable Policies Related to Bus Fleet Spare Ratios

B. Final Survey Plan and On-Line Questionnaire

C. Description and Analysis of Research Findings

D. Case Studies

E. Information from the Federal Transit Administration (FTA) concerning their Policy on Bus Fleet Spare Ratios

F. References

G. Acknowledgements

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APPENDIX A

Synopsis of Applicable Policies Related to Bus Fleet Spare Ratios

FTA CIRCULAR C 5010.1D—Grant Management Requirements

Issue Date: 11/1/2008 (replaces FTA Circular 5010.1C, "Grant Management Guidelines," dated 10-1-98)

CHAPTER IV-- PROJECT MANAGEMENT
Section 3—Equipment, Supplies, and Rolling Stock, Paragraph i (1)

i. Rolling Stock Spare Ratio Policies. Spare ratios will be taken into account in the review of projects proposed to replace, rebuild, or acquire additional vehicles. Spare ratio is defined as the number of spare vehicles divided by the vehicles required for annual maximum service. Spare ratio is usually expressed as a percentage, e.g., 100 vehicles required and 20 spare vehicles is a 20 percent spare ratio.

(1) Bus Fleet. The basis for determining a reasonable spare ratio takes local circumstances into account. The number of spare buses in the active fleet for grantees operating 50 or more fixed-route revenue vehicles should not exceed 20 percent of the number of vehicles operated in maximum fixed-route service.

For the purposes of the spare ratio calculation, "vehicles operated in maximum fixed-route service" is defined as the total number of revenue vehicles operated to meet the annual maximum service requirement. This is the revenue vehicle count during the peak season of the year, on the week and day that maximum service is provided. It excludes atypical days and special events that do not accurately depict normal peak maximum service requirements. Whether vehicles are locally funded, FTA-funded, or have exceeded their service life, the vehicles are not relevant factors. Scheduled standby vehicles are permitted to be included as "vehicle operated in maximum service."

Buses delivered for future expansion and buses that have been replaced, but are in the process of being disposed of, should not be included in the calculation of spare ratio.

For each grant application identified to acquire vehicles, a grant applicant must address the subjects of current spare ratio, the spare ratio anticipated at the time the new vehicles are introduced into service, disposition of vehicles to be replaced including information on age and mileage, and the applicant's conformance with FTA's spare ratio guidelines. An applicant is required to notify FTA if the spare ratio computation on which the grant application is based is significantly altered prior to the grant award.

FTA CIRCULAR C9030.1C-- Urbanized Area Formula Program: Grant Application Instructions

Issue Date: 10-01-98

CHAPTER V: REQUIREMENTS ASSOCIATED WITH URBANIZED AREA FORMULA GRANTS
Section 9. BUSES: Paragraph A. Requirements Related to Local Bus Fleets.

5. Spare Ratio Policies. Spare ratios will be taken into account in the review of projects proposed to replace, rebuild, or add vehicles. The basis for determining a reasonable spare bus ratio takes local circumstances into account. 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.

For purposes of the spare ratio calculation, "vehicles operated in maximum service" are defined as the total number of revenue vehicles operated to meet the annual maximum service requirement. This is the revenue vehicle count during the peak season of the year, on the week and day that maximum service is provided. It excludes atypical days and one-time special events. Scheduled standby vehicles are permitted to be included as "vehicles operated in maximum service."

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

For each grant application to acquire vehicles, a grant applicant must address the subjects of current spare ratio, the spare ratio anticipated at the time the new vehicles are introduced into service, disposition of vehicles to be replaced, and the applicant's conformance with the FTA spare ratio guideline. An applicant is required to notify FTA if the spare ratio computation on which the grant application is based is significantly altered prior to the grant award. A fleet status report must be submitted with each grant application to acquire rolling stock. "FLEET Status" and "FLEET REPLACEMENT" examples in Appendix F provide assistance in addressing spare ratio.

6. Contingency Fleet. Buses may be placed in an inactive contingency fleet-- stockpiled-- in preparation for emergencies. No bus may be stockpiled before the vehicle has reached the end of its minimum normal service life. Buses held in a contingency fleet must be properly stored, maintained, and documented in a contingency plan, updated as necessary, to support the continuation of a contingency fleet. A contingency plan is not an application requirement, although FTA may request information about the contingency fleet during application review. Contingency plans are subject to review during triennial reviews required for the Urbanized Area Formula Program. Any rolling stock not supported by a contingency plan will be considered part of the active fleet. Since vehicles in the contingency fleet are not part of the active fleet, they do not count in the calculation of spare ratio.

Appendix F: Forms and Representative Documents (C9030.1C)

(Name of Grantee)

CLASSIFICATION OF FLEET

	Before Grant Approval	Amount of Change	After Grant Approval
I. Active Fleet			
A. Peak Requirement	_____	_____	_____
B. Spares	_____	_____	_____
C. Total (A+B)	_____	_____	_____
D. Spare Ratio (B/A)	_____	_____	_____
II. Inactive Fleet			
A. Contingency Reserve	_____	_____	_____
B. Pending Disposal	_____	_____	_____
C. Total (A+B)	_____	_____	_____
III. Total Fleet			
(I.C.+II.C)	_____	_____	_____

FY 09 FTA TRIENNIAL REVIEW WORKBOOK

Issue Date: 11-1-08

SECTION 4. Satisfactory Continuing Control

Question 12. Provide an inventory of bus and paratransit vehicles owned/operated by the grantee.

For the fixed-route bus (NTD Motorbus category) please provide the following:

a. Total number revenue vehicles = _____
b. Number of vehicles required for maximum service = _____
c. Actual number of spare vehicles = _____ ("a" – "b")
d. Actual spare ratio = _____ ("c"/ "b")

Does the spare ratio exceed FTA's 20 percent guideline for bus fleets of 50 or more revenue vehicles?

Question 13. Is there a bus contingency fleet? If so, is there a contingency plan?

EXPLANATION
For grantees with 50 or more fixed route buses, a reasonable spare ratio should not exceed 20 percent of the vehicles operated in maximum fixed route service, according to FTA C 9030.1C. Maximum service means the revenue vehicle count during the peak season of the year, on the week and day that maximum service is provided. It excludes atypical days and one-time special events. Whether vehicles are locally funded, FTA funded, or the vehicles have exceeded their service life are not relevant factors. For fleets with fewer than 50 fixed-route vehicles, judgment must be applied to determine the reasonable number of spare vehicles.

The FTA recognizes two types of vehicles–active and contingency. During a period of vehicle replacement, some buses could be inactive, awaiting disposition. This is a temporary condition and can be considered a third category. However, to be not deficient, the grantee should have specific plans and dates for disposition.

Vehicles that are historic and used for parades or public relations or that have been converted to mobile offices or in other ways removed from revenue service should not be considered part of the active revenue fleet or counted in the calculation of the spare ratio.

To calculate the spare ratio, divide the number of spare vehicles by the peak requirement. The number of spare vehicles is the difference between the total fleet and the peak requirement. The peak requirement is the number of vehicles operated in maximum service.

Buses may be stockpiled in an inactive contingency fleet in preparation for emergencies. No bus may be stockpiled before it has reached the end of its service life. Buses held in a contingency fleet must be properly stored, maintained, and documented in a contingency plan. The plan should be updated as necessary, to support the continuation of a contingency fleet. These vehicles do not count in the calculation of spare ratio.

REASON FOR THE QUESTION
49 CFR 18.32
FTA C 9030.1C, Ch. V, Sections 9.a(5)-(6)
FTA C 5010.1D Ch. IV, Section 3.i

SOURCES OF INFORMATION
If the grantee has a contingency fleet, ask for a copy of its contingency plan. The grantee should provide a rolling stock roster. Pull-out logs or fueling logs can be checked to verify peak hour requirements and buses in service at the time of the site visit. The equipment records also provide a listing of the fleet.

DETERMINATION
If the grantee has a spare ratio that is 20 percent or less of the active fixed-route bus fleet, the grantee is not deficient. If the active fixed route bus fleet is greater than 50 vehicles and the spare ratio is more than 20 percent of the peak fleet, the grantee is deficient. If the grantee has a contingency fleet but no current contingency plan, the grantee is deficient. If the grantee has excessive vehicles due to the arrival of new vehicles and has no plan for disposal, the grantee is deficient.

If the grantee has fewer than 50 buses, a judgment call needs to be made based on the age of the fleet and operating conditions. A peak fleet of 40 buses with more than 8 spare vehicles is probably deficient.

SUGGESTED CORRECTIVE ACTION
If the spare ratio is excessive, the grantee must identify its approach for coming into compliance. For example, the grantee could dispose of equipment, increase its peak vehicle requirement, and/or establish a contingency fleet. Note that if the grantee submits a plan for reducing its spare ratio that cannot be completed within 90 days and is to be implemented over several quarters, progress should be reported in Milestone/Progress Reports.

In some cases, grantees may have reduced service as a result of a local or national economic downturn, which results in an increased spare ratio. If the grantee expects to resume increased operations or add new service within a reasonable period of time, it is not necessary to require that the grantee dispose of excess vehicles. The grantee should develop a bus fleet management plan to account for vehicle use, maintenance, and storage while service is reduced.

If the grantee has a contingency fleet but no contingency plan, a plan must be developed.

APPENDIX B

Final Survey Plan and On-Line Questionnaire

PROJECT DATA REQUIREMENTS

This dataset for this project will need to contain information from a large, diverse sample of transit agencies with a wide range of attributes and experiences. As well, it will be necessary to segment the data with enough detail and granularity to be able to draw conclusions from the numerous combinations of fleet/agency characteristics, and spare bus needs.

To this end, two major data sources will be used: 1) The National Transit Database (NTD); and 2) a web-based survey of bus transit organizations to be conducted as part of this project.

Data generated by these two sources will enable:

- segmentation of the sample of transit systems by different variables (by fleet size, direct operation vs. contracted out, etc.);

- examination of patterns, variations, and trends among the attributes, characteristics, performance measures, and experiences of a wide range of bus transit organizations; and

- testing for potential correlation and linkages between characteristics and variables that could be useful in developing recommendations.

The National Transit Database (NTD) (3) is a widely used source of data for transit-based analyses. Because every transit organization receiving Federal funds is required to annually report information to the NTD, it is by definition a very large and diverse sample. The NTD provides a broad blend of operational data, financial information, and performance measures--each with a common set of definitions and methodologies. The contributing transit organizations are very knowledgeable of its elements and terminology, through preparing their submittals and regularly using the NTD data sets for their own analyses.

The NTD provides robust data at the agency-wide level that can segmented into a number of sub-categories by such variables as Type of Service (e.g., Direct Operation, Purchased Transportation, etc.), Mode (Demand Response, Fixed Route Bus, Trolley Bus, etc.), or Vehicle Type (Articulated Buses, Double-Decked Buses, etc.). The NTD, however, is limited in its ability to provide more detailed information related to a transit organization's **Fleet Mix Diversity, Fuel/Energy Systems, Advanced On-Board Technologies, Service Profiles,** and detail on **Maintenance Programs**.

The modern transit fleet is essentially a diverse array of "subfleets" (a fleet subset), with each subfleet having its own technical complexity, operational constraints, and service requirements. Sufficient data must be collected to enable the analysis of these subfleets and the numerous combinations of characteristics. To that end, in order to capture the breadth and depth of data required for this Study, the NTD data will be augmented with data gathered from a web-based survey specifically designed for this project.

Attachment 1 contains the data elements of the Transit Fleet Spare Ratio Analysis Database that will be developed for this project. Data items include those to be culled from the NTD (2007 reporting year) and those to be collected from the web-based survey.

SURVEY PLAN AND INSTRUMENT

The Project Survey Plan and Instrument is designed to gather data and information from APTA member organizations that provide bus services. The survey will include a focus on the following areas:

- Fleet characteristics;
- Type of service provided and means of delivering service (i.e., Directly-operated vs. purchased transportation);
- Fleet (and Subfleet) diversity and technological characteristics/complexity;
- Range of transportation services that the fleet supports and the unique requirement of the vehicles that support those services;
- Some key elements of the maintenance program, including challenges and needs;
- Information, input, and ideas about different agency experiences with the 20% spare ratio guideline.

The Survey will be hosted through a web-based service called *SurveyGizmo*, a very powerful and flexible on-line tool. A link to the survey instrument will be e-mailed to a list (to be provided by APTA) of designated agency contacts at every APTA-member bus system. The designated respondent will be able to complete the entire survey on-line. The survey does not have to be completed in one sitting. The respondents will have the ability to save their work and then come back later to the survey instrument for completion.

The goal is to generate a large and diverse sample, "casting a wide net" across a broad cross-section of transit organizations with a wide array of:

- fleet sizes and vehicle mixes
- advanced technologies
- service attributes
- in-house and contract maintenance
- and other key factors impacting fleet management demands

The final survey instrument is contained in Attachment 2.

As a "beta test," a draft (on-line) survey instrument was initially completed by members of the project panel. This beta testing provided for the input of "real" data and text to accurately simulate and test the input, flow, and output of the survey instrument. The instrument was finalized, incorporating comments obtained from the panel—including feedback from the "beta test."

The final survey instrument became available for on-line responses from January 19, 2009 through March 4, 2009. It remained open for a period of 45 days.

It is assumed that the bus member data base provided by APTA represents the "population" of bus agencies for purposes of the research. Since the APTA data-base contained approximately 400 agencies, then a minimum response rate of 49% (or 196) would be needed to achieve a 95% confidence level (plus or minus 5%). NOTE: The actual response rate was approximately 32% (or 129 responses) providing a 90% confidence level (plus or minus 6 percent). It must be noted that this confidence level applies to survey questions pertaining to the pool as a whole. For significant conclusions to be drawn at the subfleet level, one must use caution.

The confidence calculations assume that there be a genuine random sample of the "population" (i.e., APTA member organizations that deliver bus services). Since the entire "population" will have an opportunity to respond to the survey, the project had to be sensitive to any bias that may have emerged in the response patterns.

To achieve the response goals, it was important to communicate with APTA members as to the critical importance of responding to the survey-- both before and during the survey period. A Study Overview and Update was presented at the APTA CEO Conference in late January, 2009. This was about midway through the survey field period. The presentation to the CEO's was an opportunity to spread the word and encourage the highest possible response rate by the survey's closing date. Upon closure of the field period on March 4, 2009, the survey data was downloaded into a Microsoft Excel database for formatting, clean-up, and analysis.

ATTACHMENT 1
TRANSIT FLEET SPARE RATIO ANALYSIS
PROJECT DATABASE ELEMENTS

DATA TO BE CULLED FROM THE 2007 NATIONAL TRANSIT DATABASE (NTD)
INCLUDE THE FOLLOWING:

Name of Organization
Organization Type
Service Area (Square Miles)
Service Area (Population)
Mode: Motor Bus/Trolley Bus
Type of Service: Direct Operation and/or Purchased Transportation (Contracted)
Vehicle Type
Vehicles Operated in Maximum Service (VOMS)
Vehicles Available for Maximum Service (VAMS)
Spare Ratio (Derived)
Annual Vehicle Miles
Annual Vehicle Hours
Average Operating Speed (Derived)
Unlinked Passenger Trips
Passenger Miles Traveled
Average Trip Length (Derived)
Major Mechanical Failures
Other Mechanical Failures
Total Revenue System Mechanical Failures
Labor Hours for Inspection and Maintenance
Total Active Fleet
Average Age of Fleet (in years)

ATTACHMENT 1 (CONTINUED)
TRANSIT FLEET SPARE RATIO ANALYSIS
PROJECT DATABASE ELEMENTS

DATA TO BE COLLECTED FROM THE WEB-BASED SURVEY
INCLUDE THE FOLLOWING:

GENERAL INFORMATION
Name of Organization
Contact Information for Person Responding
FLEETWIDE INFORMATION
Type of Service: Direct Operation and/or Purchased Transportation (Contracted)
Mode: Bus/Trolley Bus
Type of Bus: by Type of Service and Mode
SUBFLEET INFORMATION (BY Type of Service/Mode/Type of Bus)
Vehicles Operated In Maximum Service (VOMS)
Vehicles Available for Maximum Service (VAMS)
Spare Ratios (Derived)
Annual Vehicle Miles
Average Age of Buses
Type of Fuel/Energy Systems in Subfleet and Number of Buses with Each
Hours per Week Required to Maintain Subfleet
Hours per Week Vehicles are Available to Maintain Subfleet
Sufficiency of VAMS to provide Spare Buses required for Maintenance & Operations
Number of Additional Spare Buses Needed (if any)
FLEET-WIDE ATTRIBUTES
Types of Advanced Technology Systems present in Fleet
Bus Manufacturers Represented in Fleet
SERVICE PROFILE
Peak-to-Base Ratio
Type(s) of Bus Services Provided by Organization
Specialized Features that Each Bus Must Have to Operate in each Service Type

ATTACHMENT 1 (CONTINUED)
TRANSIT FLEET SPARE RATIO ANALYSIS
DATABASE

DATA TO BE DRAWN FROM THE WEB-BASED SURVEY (CONTINUED)

MAINTENANCE PROGRAM
Number of Trained Mechanics/Technicians Required to Maintain Entire Fleet
Number of Trained Mechanics/Technician Positions Budgeted
Number of Maintenance Shifts Run at Garage(s)
Mid-Life Scheduled Overhaul Program
Scheduled Component Change-Out Program before Failure
Parts or Components with Extraordinarily Long Procurement Lead Times
Consistent Bus Replacement and/or Rehabilitation Schedule
Inactive Reserve Fleet and, if so, Number of Buses
FTA EXPERIENCES
Has Organization ever had to exceed FTA 20% Spare Ratio Rule?
Has Organization ever Requested a Variance on Rule from FTA? Outcomes?
PERSPECTIVES AND INPUT
Specific Actions Taken by Organization to Maintain or Lower Spare Ratio
How does FTA 20% Spare Ratio Rule Impact your Organization
Suggestions on Modifying FTA Spare Ratio Rule to Address any Adverse Impacts

ATTACHMENT 2
Transit Bus Fleet Spare Ratio Analysis
Survey Instrument

==========

Bus Fleet Spare Ratio Analysis—On-Line Survey
Questionnaire Hard Copy
Due Date: February 28, 2009

==========

WELCOME

==========

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

Organization Name _____

First Name _____

Last Name _____

Title _____

Street Address _____

Suite/Office _____

City _____

State _____

Postal Code _____

Country _____

Email Address _____

Phone Number _____

Fax Number _____

Mobile Phone _____

==========
BUS FLEET DATA
==========

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

   ( ) Directly operated, fixed-route bus services
   ( ) Contracted (purchased transportation), fixed-route bus services

3. Please check below each type of bus that your agency has in its DIRECTLY-OPERATED, FIXED-ROUTE active 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)
   ( ) Other (please specify)
   ( ) Other (please specify)

4. Please check below each type of bus that your agency has in its CONTRACTED, FIXED-ROUTE active 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)
   ( ) Other (please specify)
   ( ) Other (please specify)

==========
SUBFLEET INFORMATION--DIRECTLY OPERATED, FIXED ROUTE
==========

5. Please specify the number of Vehicles Operated in Maximum Service (VOMS)in this SUBFLEET:***[Answer this question for each bus type checked in Question #3]***

   _____

6. Please specify the number of all active Vehicles Available for Maximum Service (VAMS) for this SUBFLEET--(this includes ALL buses in this SUBFLEET):***[Answer this question for each bus type checked in Question #3]***

   _____

7. What are the Annual Vehicle Miles for this SUBFLEET? ***[Answer this question for each bus type checked in Question #3]***

   _____

8. What is the Average Age (in years) of the buses in this SUBFLEET: ***[Answer this question for each bus type checked in Question #3]***

   _____

9. Please check the type of fuel/energy systems represented in this SUBFLEET, and enter the number of buses in the SUBFLEET powered by each system: ***[Answer this question for each bus type checked in Question #3]***

	Present in Subfleet	Number of Buses	Comments
Gasoline	( )	_____	_____
Diesel	( )	_____	_____
CNG	( )	_____	_____
LNG	( )	_____	_____
Propane	( )	_____	_____
Hybrid-Electric (Gasoline)	( )	_____	_____
Hybrid-Electric (Diesel)	( )	_____	_____
Battery-Electric	( )	_____	_____
Fuel Cell	( )	_____	_____
Other 1 (please describe in Comments column)	( )	_____	_____
Other 2 (please describe in Comments column)	( )	_____	_____
Other 3 (please describe in Comments column)	( )	_____	_____

10. Do the active Vehicles Available for Maximum Service (VAMS) previously specified for this SUBFLEET provide a sufficient number of spare buses to repair, maintain (including PM's), service, and fuel this SUBFLEET and meet daily operational requirements? ***[Answer this question for each bus type checked in Question #3]***

    ( ) Yes
    ( ) No

11. How many additional spare buses are needed for this SUBFLEET? ***[Answer this question for each bus type checked in Question #3]***

    _____

12. Please list the primary reasons why the additional buses are needed. ***[Answer this question for each bus type checked in Question #3]***

    _____
    _____
    _____
    _____
    _____

13. Does the Spare Ratio for this SUBFLEET currently exceed 20%?***[Answer this question for each bus type checked in Question #3]***

    ( ) Yes
    ( ) No

14. Please briefly explain why. ***[Answer this question for each bus type checked in Question #3]***

    _____
    _____
    _____
    _____
    _____

15. Has this larger SUBFLEET spare ratio adversely impacted other SUBFLEETS? If so, please explain. ***[Answer this question for each bus type checked in Question #3]***

    _____
    _____
    _____
    _____
    _____

==========
SUBFLEET INFORMATION--CONTRACTED, FIXED-ROUTE
==========

16. Please specify the number of Vehicles Operated in Maximum Service VOMS) in this SUBFLEET:***[Answer this question for each bus type checked in Question #4***

    _____

17. Please specify the number of all active Vehicles Available for Maximum Service (VAMS) for this SUBFLEET--(this includes ALL buses in this SUBFLEET): ***[Answer this question for each bus type checked in Question #4]***

    _____

18. What are the Annual Vehicle Miles for this SUBFLEET? ***[Answer this question for each bus type checked in Question #4]***

    _____

19. What is the Average Age (in years) of the buses in this SUBFLEET: [***Answer this question for each bus type checked in Question #4]***

    _____

20. Please check the type of fuel/energy systems represented in this SUBFLEET, and enter the number of buses in the SUBFLEET powered by each system: ***[Answer this question for each bus type checked in Question #4]***

	Present in Subfleet	Number of Buses	Comments
Gasoline	( )	_____	_____
Diesel	( )	_____	_____
CNG	( )	_____	_____
LNG	( )	_____	_____
Propane	( )	_____	_____
Hybrid-Electric (Gasoline)	( )	_____	_____
Hybrid-Electric (Diesel)	( )	_____	_____
Battery-Electric	( )	_____	_____
Fuel Cell	( )	_____	_____
Other 1 (please describe in Comments column)	( )	_____	_____
Other 2 (please describe in Comments column)	( )	_____	_____
Other 3 (please describe in Comments column)	( )	_____	_____

21. Do the active Vehicles Available for Maximum Service (VAMS) previously specified for this SUBFLEET provide a sufficient number of spare buses to repair, maintain (including PM's), service, and fuel this SUBFLEET and meet daily operational requirements? ***[Answer this question for each bus type checked in Question #4]***

    ( ) Yes
    ( ) No

22. How many additional spare buses are needed for this SUBFLEET? ***[Answer this question for each bus type checked in Question #4]***

    _____

23. Please list the primary reasons why the additional buses are needed. ***[Answer this question for each bus type checked in Question #4]***

    _____
    _____
    _____
    _____
    _____

24. Does the Spare Ratio for this SUBFLEET currently exceed 20%? ***[Answer this question for each bus type checked in Question #4]***

    ( ) Yes
    ( ) No

25. Please briefly explain why. ***[Answer this question for each bus type checked in Question #4]***

    _____
    _____
    _____
    _____
    _____

26. Has this larger SUBFLEET spare ratio adversely impacted other SUBFLEETS? If so, please explain. ***[Answer this question for each bus type checked in Question #4]***

    _____
    _____
    _____
    _____
    _____

==========
FLEET-WIDE ATTRIBUTES
==========

27. Please check each advanced technology system that is present within your ENTIRE BUS FLEET (both directly operated and contracted out):

    ( ) 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
    ( ) Other (please specify)
    ( ) Other (please specify)
    ( ) Other (please specify)
    ( ) None of the Above
    ( ) Regenerative Braking
    ( ) Electronic Head Signs
    ( ) Closed Area Networks
    ( ) Remote Diagnostics
    ( ) Hazard Detection/Response Systems

28. Has the addition of these advanced technologies affected your ability to keep your entire active fleet within the 20% Spare Ratio standard?

    ( ) Yes
    ( ) No

29. Please briefly explain.

    _____
    _____
    _____

30. What are some of the reasons that your agency has implemented these advanced technology systems? Please check all that apply.

    ( ) Customer Demand
    ( ) Customer Comfort and/or Convenience
    ( ) Marketing Benefits
    ( ) Improved Efficiency
    ( ) Reduced Operating and/or Maintenance Costs
    ( ) Environmental Benefits
    ( ) Compliance with External Regulations or Directives
    ( ) Safety Enhancement
    ( ) Other (please specify)
    ( ) Other (please specify)
    ( ) Other (please specify)
    ( ) None of the Above

31. Please check all of the bus manufacturers that are represented in your ENTIRE BUS FLEET (both directly operated and contracted out):

( ) Gillig
( ) New Flyer
( ) North American Bus Industries (NABI)
( ) Optima
( ) Orion
( ) RTS
( ) Other (please specify)
( ) Other (please specify)
( ) Other (please specify)
( ) Other (please specify)
( ) Ford
( ) GM

==========
SERVICE PROFILE
==========

32. What is the Peak-to-Base Ratio of your DIRECTLY-OPERATED, FIXED-ROUTE SERVICES? Please use the highest number of vehicles required during the peak period, divided by the lowest bus requirement during the base (off-peak) period.

    _____

33. What is the Peak-to-Base Ratio of your CONTRACTED, FIXED ROUTE SERVICES. Use the highest number of vehicles required during the peak period, divided by the lowest bus requirement during the base (off-peak) period.

    Please enter this Ratio for the fleet maintained by each contractor, as applicable. If you have no Contractors, please disregard this question.

    Contractor 1 _____
    Contractor 2 _____
    Contractor 3 _____
    Contractor 4 _____
    Contractor 5 _____
    Contractor 6 _____

34. What type(s) of bus services are provided by your fixed-route fleet? Please check all that apply.

    ( ) Bus Rapid Transit (BRT)
    ( ) Commuter Express (non-BRT)
    ( ) Regional Trunk
    ( ) Local Route
    ( ) Neighborhood Circulator
    ( ) Shuttle
    ( ) Special Event
    ( ) Back-Up for Rail Service Outages
    ( ) Emergency
    ( ) Other (please specify)
    ( ) Other (please specify)
    ( ) Other (please specify)

==========
SERVICE PROFILE CONTINUED
==========

35. What specialized features MUST a bus have in order to operate in each type of service? ***[Answer this question for each service type checked in Question #34]***

    ( ) High passenger-carrying capacity (i.e., more than a standard 40-foot 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
    ( ) Other (please specify)
    ( ) Other (please specify)
    ( ) Other (please specify)
    ( ) Other (please specify)
    ( ) None of the Above
    ( ) More than one door

36. Has the lack of available buses equipped with these essential Specialized Features affected your ability to meet daily pull-out requirements of any of your services? If so, please briefly explain.

    _____
    _____
    _____
    _____
    _____

==========
MAINTENANCE PROGRAM
==========

37. How many trained mechanics/technicians are required to maintain your entire bus fleet (including all subfleets)? Please answer in Full-Time Equivalent (FTE) employees.

    _____

38. How many trained mechanics/technician positions do you presently have budgeted to meet your entire bus fleet's maintenance requirements? Please answer in FTE's.

    _____

39. What, if any, challenges has your organization experienced in Attracting, retaining, and training qualified mechanics/technicians?

    _____
    _____
    _____
    _____
    _____

40. How has your organization supported the implementation of advanced on-board technologies and/or fueling/energy systems in terms of providing required resources (e.g., additional staffing, new equipment, expanded shop capabilities, etc.)?

    _____
    _____
    _____
    _____
    _____

41. On average, how many maintenance shifts do you typically run at your maintenance garage(s)?

    ( ) One Shift
    ( ) Two Shifts
    ( ) Three Shifts
    ( ) Other (please specify in box)

42. Does your organization have a mid-life scheduled overhaul program for major components?

    ( ) Yes
    ( ) No

43. Please briefly describe the major elements of the program.

_____
_____
_____
_____
_____

44. Does your organization have a Scheduled Component Change-Out Program, preemptively replacing components before failure based upon manufacturers recommendations and/or predictive failure analysis?

( ) Yes
( ) No

45. Please briefly explain:

_____
_____
_____
_____
_____

46. Please describe major parts or components that have an extraordinarily long lead time to procure, resulting in significantly extended bus down time.

_____
_____
_____
_____
_____

==========
MAINTENANCE PROGRAM (CONTINUED)
==========

47. Does your organization have a consistent bus replacement or major rehabilitation schedule?

    ( ) Yes
    ( ) No

48. Under this schedule, at what age (in years) is a bus replaced or rehabbed?

    Replaced _____
    Rehabbed _____
    If neither applicable, enter zero _____

49. Does your organization have an inactive reserve fleet?

    ( ) Yes
    ( ) No

50. How many vehicles are typically kept in inactive reserve?

    _____

==========
FTA EXPERIENCES
==========

51. Has your organization ever had to exceed the 20% Spare Ratio rule?

( ) Yes
( ) No
( ) Not Sure

52. Please briefly describe the situation:

_____
_____
_____
_____
_____

53. Has your organization ever requested a variance from the FTA with regard to the 20% Spare Ratio Rule?

( ) Yes
( ) No

54. Please briefly describe the outcome(s):

_____
_____
_____
_____
_____

==========
PERSPECTIVES AND INPUT
==========

55. What specific actions has your organization taken to maintain or lower its spare bus ratio? (OPTIONAL)

_____
_____
_____
_____
_____

56. If not already mentioned, are there any other ways that compliance with the 20% Spare Ratio Rule impacts your organization (OPTIONAL)?

_____
_____
_____
_____
_____

57. How would you suggest modifying the 20% Spare Ratio Rule to address any adverse impacts that your organization is experiencing? (OPTIONAL)

_____
_____
_____
_____
_____

THIS IS THE LAST QUESTION: Your complete response is very important. Before clicking on the "Finished/Submit" button below, please click to go back through each previous page and double check to make sure all questions are answered.

==========
Thank You!
==========

Thank you for your time and energy in completing this survey!

Your participation is a critical element of the Bus Spare Ratio Analysis project and will be invaluable in developing recommendations.

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APPENDIX C

Description and Analysis of Research and Findings

Description and Analysis of Research and Findings

This section describes analysis data collected in the research in and key findings in each of the following areas:

A. NATIONAL SPARE RATIO DESCRIPTIVE STATISTICS

B. NATIONAL SPARE RATIO CORRELATION WITH OTHER FACTORS

C. ATTRIBUTES OF SURVEYED AGENCIES

D. SURVEYED FLEET MIX COMPLEXITY

   1. Bus Size and other Subfleet Attributes

   2. Subfleet Spare Ratios

   3. Fuel/Energy Propulsion Systems

   4. On-Board Advanced Technology

   5. Diversity of Manufacturers

E. SURVEYED SERVICE MIX PROFILE AND INTERCHANGABILITY

F. MAINTENANCE PROGRAM CHALLENGES

A. National Spare Ratios Descriptive Statistics

Using 2007 National Transit Database (NTD) Data for bus systems, the Means, Medians, Frequency Distributions, and Standard Deviations have been computed for analysis.

According to the 2007 National Transit Database (NTD), the average (mean) spare ratio for Fixed-Route fleets **with *50 or more buses*** was:

- 24.7% for *Directly-Operated* bus fleets, and
- 24.6% for *Purchased Transportation*, Fixed-Route bus fleets .

NTD data for Fixed-Route fleets ***with fewer than 50 buses*** showed the average spare ratio to be:

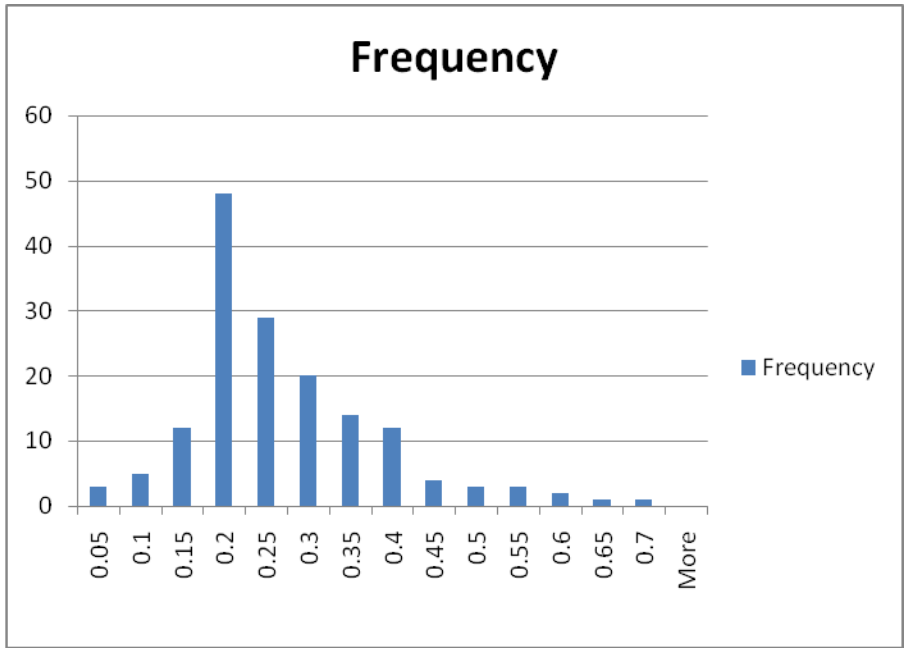
- 40.0% for *Directly-Operated*, Fixed-Route bus fleets, and
- 37.7% for *Purchased Transportation*, Fixed-Route bus fleets.

Please refer to the spare ratio frequency distribution data and related statistical summaries below.

APPENDIX C1-SPARE RATIO FREQUENCY ANALYSIS

FIXED-ROUTE, DIRECT OPERATION-- Agencies with 50 Buses or More

	Stats	*Spare Ratios*	*Frequency*
Count	157	0-5%	3
		6-10%	5
Mean Spare Ratio	24.7%	11-15%	12
Median Spare Ratio	22.0%	16-20%	48
		21-25%	29
Minimum Spare Ratio	1.5%	26-30%	20
Maximum Spare Ratio	65.9%	31-35%	14
		36-40%	12
		41-45%	4
		46-50%	3
		51-55%	3
		56-60%	2
		61-65%	1
		66-70%	1
		More	0



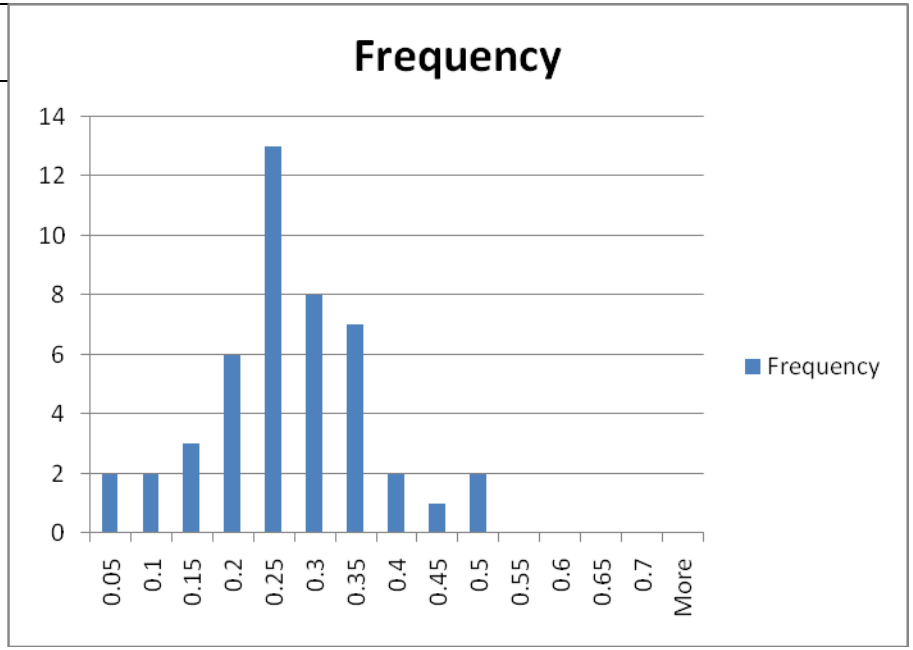
Source: 2007 National Transit Database

Note: 2 outliers were removed from this count with spare ratios of 111% and 174%.

APPENDIX C2--SPARE RATIO FREQUENCY ANALYSIS
(continued)

FIXED-ROUTE, PURCHASED TRANSPORTATION--Agencies with 50 Buses or More

	Stats	*Spare Ratios*	*Frequency*
Count	46	0-5%	2
		6-10%	2
Mean Spare Ratio	24.6%	11-15%	3
Median Spare Ratio	24.5%	16-20%	6
		21-25%	13
Minimum Spare Ratio	4.1%	26-30%	8
Maximum Spare Ratio	48.8%	31-35%	7
		36-40%	2
		41-45%	1
		46-50%	2
		51-55%	0
		56-60%	0
		61-65%	0
		66-70%	0
		More	0



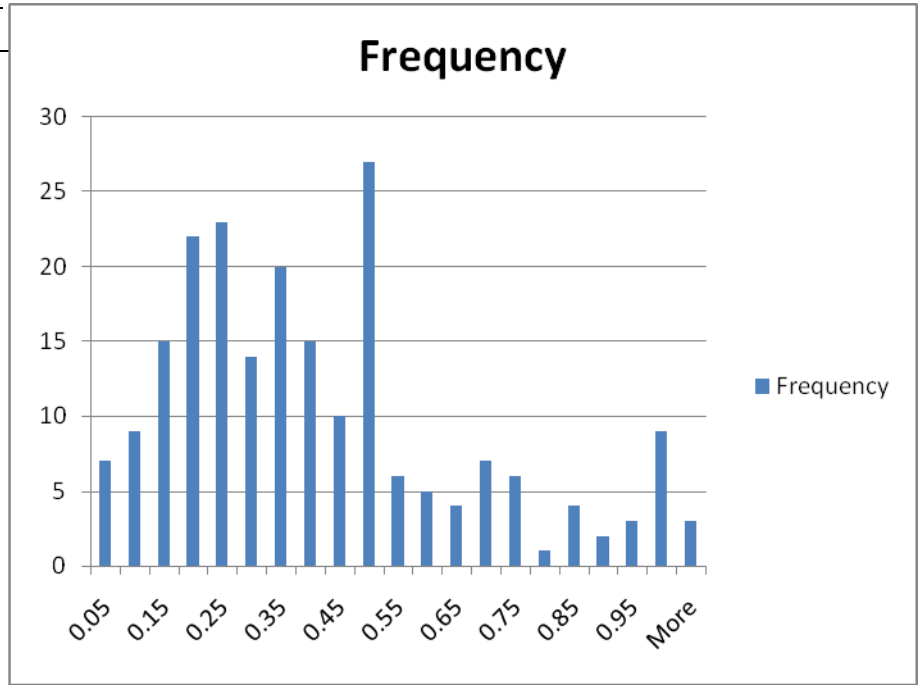
Source: 2007 National Transit Database

Note: 1 outlier was removed from this count with spare ratio of 93%.

APPENDIX C3--SPARE RATIO FREQUENCY ANALYSIS
(continued)

FIXED-ROUTE DIRECT OPERATION--Agencies with Fewer than 50 buses

	Stats	*Spare Ratios*	*Frequency*
Count	212	0-5%	7
		6-10%	9
Mean Spare Ratio	40.0%	11-15%	15
Median Spare Ratio	33.8%	16-20%	22
		21-25%	23
Minimum Spare Ratio	0.0%	26-30%	14
Maximum Spare Ratio	136.4%	31-35%	20
		36-40%	15
		41-45%	10
		46-50%	27
		51-55%	6
		56-60%	5
		61-65%	4
		66-70%	7
		71-75%	6
		76-80%	1
		81-85%	4
		86-90%	2
		91-95%	3
		96-100%	9
		More	3



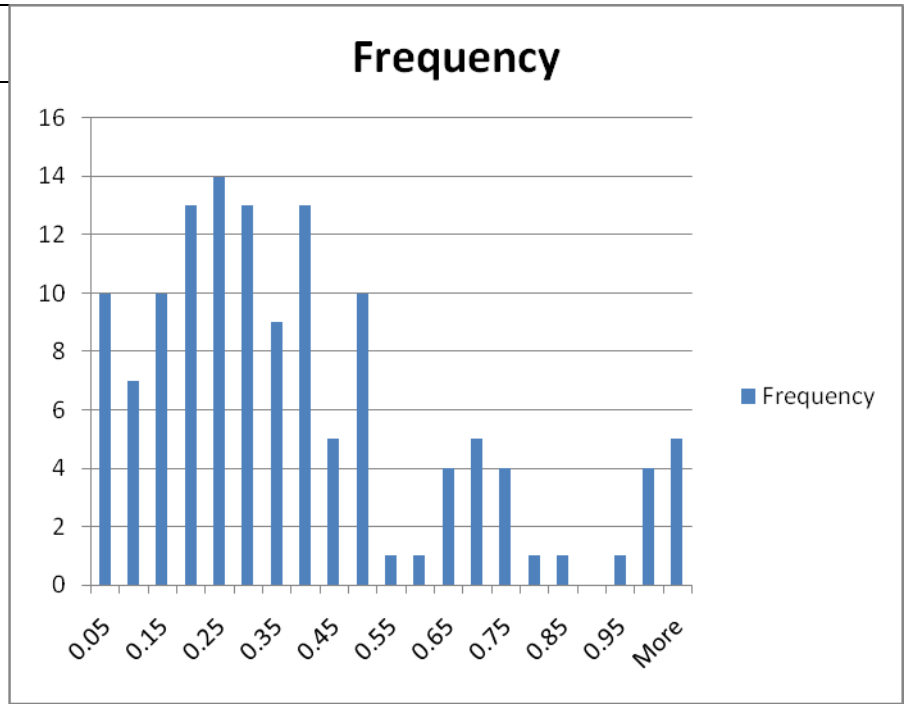
Source: 2007 National Transit Database

Note: 3 outliers were removed from this count with spare ratios of 200%, 200%, and 650%.

APPENDIX C4--SPARE RATIO FREQUENCY ANALYSIS
(continued)

*FIXED-ROUTE PURCHASED TRANSPORTATION--**Agencies with Fewer than 50 Buses***

	Stats	*Spare Ratios*	*Frequency*
Count	131	0-5%	10
		6-10%	7
Mean Spare Ratio	37.7%	11-15%	10
Median Spare Ratio	29.6%	16-20%	13
		21-25%	14
Minimum Spare Ratio	0.0%	26-30%	13
Maximum Spare Ratio	150.0%	31-35%	9
		36-40%	13
		41-45%	5
		46-50%	10
		51-55%	1
		56-60%	1
		61-65%	4
		66-70%	5
		71-75%	4
		76-80%	1
		81-85%	1
		86-90%	0
		91-95%	1
		96-100%	4
		More	5



Source: 2007 National Transit Database

Note: 1 outlier was removed from this count with a spare ratio of 550%.

The "50 or more bus fleet" median spare ratios are 22.0% for the *directly-operated* fleets and 24.5% for the *purchased transportation* fleets. Thus, one-half of each of the fleets, *directly-operated* and *purchased transportation*, had a spare ratio greater than 22.0% and 24.5% respectively. For the *directly-operated* fleets, 29 had a spare ratio between 21% and 25% and an additional 20 of those fleets had spare ratios between 26% and 30%. A full 40 of the 157 fleets tabulated had a spare ratio over 30%.

To view how spare ratio averages may have changed over time, the means and standard deviations of spare ratios were drawn from the 1990 NTD (formerly known as Section 15) as presented in a document entitled *National Bus Spare Ratio Study* (1). This study was published by the FTA Office of Capital and Formula Assistance in March 1993. The following table compares the means and standard deviations by fleet size category between 1990 and the 2007 data:

YEAR	VOMS RANGE	MEAN	STD DEV	SAMPLE SIZE
1990	50-99	27.1%	11.3%	26
2007	50-99	25.3%	11.8%	44
1990	100-249	25.4%	10.0%	28
2007	100-249	22.2%	9.1%	48
1990	250-499	19.4%	6.0%	15
2007	250-499	24.4%	10.6%	14
1990	500-999	19.5%	4.3%	11
2007	500-999	25.7%	11.2%	13
1990	1000 and >	22.2%	9.7%	7
2007	1000 and >	18.1%	10.8%	7

Regarding the comparison between 1990 and 2007 NTD Spare Ratio data for Fixed-Route Directly Operated Fleets:

- for fleets with 50-99 Vehicles Operated in Maximum Service (VOMS), the mean spare ratio went down from 27.1% in 1990 to 25.3% in 2007; still significantly over 20%. The standard deviation (measuring the range of variance from the mean) was virtually unchanged from 11.3 in 1990 to 11.8% in 2007.

- for fleets with 100-249 VOMS, the mean spare ratio went down from 25.4% in 1990 to 22.2% in 2007; still above 20%, though not as much as the 50-99 VOMS category. The standard deviation changed slightly from 10.0 to 1990 to 9.1% in 2007.

- for fleets with 250-499 VOMS, the mean spare ratio went up dramatically from 19.5% in 1990 to 25.7% in 2007; well above 20%. The standard deviation changed significantly from 6.0% to 1990 to 10.6% in 2007, indicating the latter's wider distribution of spare ratio values relative to the mean.

- for fleets with 500-999 VOMS, the mean spare ratio also went up dramatically from 19.4% in 1990 to 24.4% in 2007; well above 20%. The standard deviation jumped quite significantly from 4.3% to 1990 to 11.2% in 2007, indicating an even wider distribution of spare ratio values relative to the mean than in the 250-499 VOMS category.

- for fleets with 1000 or more VOMS, the mean spare ratio also went down from 22.2% in 1990 to 18.1% in 2007; now below 20%. The standard deviation changed from 9.7% to 1990 to 10.8% in 2007, indicating much more limited shift in the distribution of spare ratio values.

FINDINGS

In examining the 2007 NTD data presented above, one can make some initial, inferences:

- The average spare ratios, for the "50 or more bus fleets," of 24.7% and 24.6% do *not* appear to be significantly higher than a 20% spare ratio.

- Those "50 or more bus" fleets have a significantly lower average spare ratio than the "fewer than 50 bus" fleets.

- There appears to be little difference between the average spare ratios of Directly-Operated and Purchased Transportation fleets within each of the two fleet size categories.

In further looking at the 157 fixed-route, *directly-operated* bus fleets with 50 or more vehicles, the spare ratios range from a low of 1.5% to a high of 65.9 percent. Similarly, the range of spare ratios for the 46 counterpart *purchased transportation* fleets range from 4.1% to 48.8 percent. The high ends of both ranges are significantly above the 20% spare ratio guideline.

Over time, agency spare ratios (as reported in the National Transit Database) have increased significantly since 1990 in both the 250-499 and 500-999 Vehicles Operated in Maximum Service (VOMS) fleet categories. In 2007, the mean spare ratio for the 250-499 VOMS category

was 24.4%; and for the 500-999 bus fleets it was 25.7%. This represents an increase in the mean of 5.0% and 6.2% respectively, from 1990.

Although decreasing from 1990 in the 50-99 and 100-249 VOMS categories, the 2007 averages are still above a 20% spare ratio by 5.3% above and by 2.2% above, respectively. For the nation's largest bus fleets in the "1000 or more" VOMS category, there is a moderate downward change in the average spare ratio from 1990. This fleet category is the only one whose actual average spare ratio (18.1% in 2007) is below 20%.

B. National Spare Ratio Correlation with Other Factors

To better understand the factors that are correlated (or not) with the number of spare buses in transit agency fleets, a correlation analysis was performed using 2007 NTD data for several potentially explanatory variables. This analysis involved the calculation of "Coefficients of Determination" (or "R-squared") for several different pairs of variables.

The Coefficient of Determination is used to assess the strength of the linear relationship between variables. An R-squared value of 1.00 indicates a "perfect" linear relationship; while an R-squared value of 0.00 indicates no relationship between the values (an R-Squared value of minus-1.00 indicates a perfect, inverse relationship). A value of 0.70 is considered a moderately strong relationship while 0.80 and greater reflects a very strong relationship between the variables. Conversely, an R-squared of less than 0.50 down to 0.00 indicates a weak relationship.

The Spare Ratio formula is rooted in the basis that there is a strong linear relationship between the number of Spare Buses held by an agency and the number of Vehicles Operating in Maximum Service (VOMS). To test the strength of this and other possible relationships, Coefficients of Determination were calculated for the Spare Bus variable in conjunction with several other variables, including:

- VOMS
- Annual Revenue Miles
- Revenue Service Operating Speed (Vehicle Revenue Miles/Vehicle Revenue Hours)
- Major Mechanical Failures
- Labor Hours for Inspection & Maintenance

The tables below summarize the R-squared values resulting from the testing of the NTD Fixed-Route, Directly-Operated Spare Bus data and selected pairs of other variables under different fleet size conditions:

CORRELATION BETWEEN SPARE BUSES AND :	***All Fleets***	***Fleets < 50 Revenue Vehicles***	***Fleets 50-249 Revenue Vehicles***	***Fleets 50-499 Revenue Vehicles***	***Fleets 500-1000+ Revenue Vehicles***	***Fleets 250-1000+ Revenue Vehicles***
Vehicles Operated in Maximum Service (VOMS)	**.90**	.14	.25	.53	**.81**	**.85**
Annual Vehicle Revenue Miles	**.89**	.18	.21	.45	**.75**	**.82**
Revenue Operating Speed	.04	<.01	<.01	.02	.27	.14
Major Mechanical Failures	**.79**	.04	.20	.33	.60	.66
Labor Hours for Inspection & Maintenance	**.82**	.14	.14	.43	**.74**	**.78**

NOTE: Strong R-squared values of over 0.70 are noted in **bold.**

The Spare Ratio, by its definition, is intended to reflect a strong linear relationship between the number of Spare Buses and the number of Vehicles Operating in Maximum Service (VOMS). The correlation analysis of all of the NTD-reporting fixed-route, directly-operated bus systems (summarized in the table above) does not wholly support that premise.

The R-squared values in the table above indicate the following:

- While there is a strong correlation (0.90) indicated between Spare Buses and VOMS when looking at all fleets (i.e., all sizes), that correlation strength drops down dramatically when segregating the fleets by their relative size. The R-squared value for bus fleets with fewer than 50 revenue vehicles is only 0.14.

- However, when grouping the fleets with 50-249 revenue vehicles, the relationship between Spare Buses and VOMS is still very weak (0.25). While it improves somewhat when broadening the range from 50-499 revenue vehicles, the strength of the relationship is mediocre (0.53).

- The strong relationship between Spare Vehicles and VOMS appears to only occur at the large end of the fleet spectrum. When grouping fleets with between 250 and over 1000 revenue vehicles, the correlation is a strong 0.85. When focusing on fleets with even more revenue vehicles, 500 to over 1000 buses, the correlation is similar at a strong 0.81.

This analysis indicates that the number of Vehicles Operated in Maximum Service is not a strong indicator of the need for Spare Buses in fleets with fewer than 250 revenue vehicles. The strongest relationship between Spare Buses and VOMS appears to occurs in fleets with more than 250 buses, and on beyond 1000 vehicles.

If the Spare Bus-to-VOMS relationship is weak for all but the nation's largest bus fleets, then what strongly correlated variable(s) may be useful in determining the appropriate need for Spare Buses in small to mid-sized fleets?

Four other variables were tested in terms of the strength of their individual relationship with Spare Buses: Annual Vehicle Revenue Miles, Revenue Operating Speed, Major Mechanical Failures, and Labor Hours for Inspection and Maintenance.

As with the VOMS experience, there was a strong relationship between Spare Buses and Annual Vehicle Revenue Miles (.89), and between Spare Buses and Labor Hours for Inspection and Maintenance (0.82) when grouping all fleets regardless of size. Both relationships weakened considerably when looking at fleets with fewer than 500 vehicles, with R-squared values ranging from 0.00 to 0.45. As with VOMS, the correlation of these two variables with Spare Buses was strongest in the fleets with 250 buses or more: Spare Buses and Annual Vehicle Revenue Miles (.82) and Spare Buses and Labor Hours for Inspection and Maintenance (.78).

For the correlation between Spare Buses and Major Mechanical Failures, there was also a fairly strong relationship indicated (.79) when grouping all fleet sizes together. However, this relationship weakened significantly when examining fleets with fewer than 500 buses (between 0.04 and 0.33). In the larger fleet grouping (250 or more buses), the relationship between Spare Buses and Major Mechanical failures improved to 0.66, stronger but not stellar.

FINDINGS

In summary, this analysis indicated that using VOMS as an indicator of spare bus needs is very weak for fleets up to 250 buses, with some additional strength shown when including fleets up to 499 vehicles. However, it appears that VOMS could be a very strong indicator for larger fleet (with 250 buses or more) spare bus requirements. Although many relationships were tested, this analysis could not identify a stronger alternative variable for small to mid-sized bus fleets (between 0 and 500 buses) that may be a better indicator of Spare Bus needs than Vehicles Operated in Maximum Service (VOMS).

C. Attributes of Surveyed Agencies

The special on-line survey of APTA member bus agencies provided a wealth of data and information, both quantitative and anecdotal. Following is a profile of the respondents to the survey:

- 129 Complete Agency Responses
- 26 Partial Agency Responses
- 113 Agencies with Directly-Operated (DO) Fleets
- 33 Agencies with Purchased Transportation (PT) Fleets
- 17 Agencies with both Directly Operated and Purchased Transportation Fleets
- 107 U.S. Agencies with National Transit Database (NTD) Entries
- 16 U.S. Agencies without NTD Entries
- 6 Canadian Agencies (non-NTD Participants)

To gauge the representation of the survey to the "population" of APTA member bus agencies, the following table summarizes the survey sampling by Fleet Vehicles Operated in Maximum Service (VOMS) and compares it with the NTD distribution of *directly-operated* (DO) and *purchased transportation* (PT) agency fleets. The Fleet VOMS of the sampled agencies represents their combined DO plus PT fleets.

Two counts of NTD agencies fleets are provided: DO Fleets only and DO plus PT Fleets. Because some agencies have both DO and PT operated fleets, one cannot just add the two numbers together. The actual number of combined agency fleets by VOMS category is somewhere in between "DO only" and "DO plus PT" numbers. For example, the NTD number of combined DO and PT agency fleets for the 1 to 49 VOMS category is somewhere between 243 and 380 (or between 66% and 71 % of the total).

In reviewing the table below, the following conclusions can be drawn regarding the sampled agencies and their distribution by different fleet sizes:

- The 1-49 VOMS Fleet Group appears to be underrepresented: 33% vs. 66-71%
- The 50-99 VOMS Fleet Group appears to be overrepresented: 19% vs. 12%
- The 100-249 VOMS Fleet Group appears to be overrepresented: 22% vs. 11-13%
- The 250-499 VOMS Fleet Group appears to be overrepresented: 12% vs. 3-4%
- The 500-999 VOMS Fleet Group appears to be overrepresented: 9% vs. 2-3%
- The 1000+ VOMS Fleet Group appears to be overrepresented: 5% vs. 1-2%

This over or underrepresentation should not make a significant difference in analyses that are based upon the survey results and conclusion drawn, however, the reader should be aware that the sub-sampling of bus fleets within the 129 completed survey responses does not exactly track the Fleet Group distribution the NTD "universe" of agency fleets. One should use caution in drawing conclusions within the subfleet level, given the significantly lower numbers in the subsample.

VOMS Fleet-Size Group s (Combined DO+PT Fleets)	Completed Survey Responses	Pctg. of Total Survey Responses	NTD COUNT DO Fleets Only	NTD COUNT DO+PT Fleets	Pctg. of Total DO Fleets only	Pctg. of Total DO+PT Fleets
01-49	42	33%	243	380	66%	71%
50-99	25	19%	44	64	12%	12%
100-249	28	22%	48	59	13%	11%
250-499	16	12%	14	14	4%	3%
500-999	11	9%	13	13	3%	2%
1000+	7	5%	7	7	2%	1%
TOTAL	129	100%	369	537	100%	100%

Following are additional attributes of the agencies that responded to the on-line survey. This information is based upon the 2007 NTD data submitted by the agency. Consequently, the statistics below represent only 107 of the 129 complete respondents; the remaining 22 were not required to submit NTD data (16 small systems and 6 Canadian systems).

Agency Service Area Attributes

	Population Served	Land Area Served (Sq. Mi)	Population Density
MEAN	942,368	463	3,219
MEDIAN	559,062	288	2,123
HIGHEST	8,493,281	2,725	24,948
LOWEST	49,920	30	437

Agency Ridership Attributes

	Annual Passenger Miles	Annual Unlinked Trips	Average Trip Length
MEAN	111,386,029	32,957,381	4.7
MEDIAN	37,652,550	8,939,334	4.0
HIGHEST	1,812,108,125	862,630,526	18.5
LOWEST	818,660	87,185	1.2

Agency Operational Attributes

	Annual Vehicle Revenue Miles	Annual Vehicle Revenue Hours	Revenue Operating Speed
MEAN	9,703,901	832,301	13.7
MEDIAN	4,193,093	332,137	13.2
HIGHEST	101,303,184	13,079,928	26.5
LOWEST	359,000	13,554	7.7

Agency Fleet Attributes

	VOMS	Spare Ratio	Avg. Fleet Age (Years)
MEAN	264	26%	7.0
MEDIAN	116	23%	7.0
HIGHEST	3,896	110%	12.6
LOWEST	8	0%	3.6

FINDINGS

The statistics in these tables illustrate the tremendous variation among agencies responding to the survey in Service Area, Ridership, and Operational, and Fleet characteristics. It is reasonable to infer that the highly diverse "population" of transit agencies in the U.S. and Canada is sufficiently represented by the survey sample.

D. Surveyed Fleet Mix Complexity

To complement the higher level fleet data provided in the NTD, the survey was able to gather more granular information at the subfleet and fleet-wide level in terms of:

- Bus Size/Type and other Subfleet Attributes
- Subfleet Spare Ratios
- Fuel/Energy Propulsion Systems
- On-Board Advanced Technology Systems, and
- Diversity of Manufacturers.

The purpose of this section is to assess and better understand the variability, diversity, and complexity of today's transit bus fleets and gauge the impact on spare bus needs.

1. Bus Size/Type and Other Subfleet Attributes

U.S. and Canadian transit systems operate a wide range of vehicle sizes and types. There were 15 primary subfleet categories that emerged from the survey, including:

- Less-than-30-foot bus (including vans)
- 30-foot bus
- 35-foot bus
- 35-foot mountain grade bus
- 40-foot standard bus
- 40-foot commuter/suburban (2-axle)
- 40-foot trolley bus (overhead catenary)
- 40-foot BRT bus
- Over-the-Road (3-axle) bus
- 45-foot (not Over-the Road) bus
- 60-foot articulated standard bus
- 60-foot articulated trolley bus (overhead catenary)
- 60-foot articulated BRT bus
- Double-Decker Bus
- Rubber-Tired trolley replica bus

The following table summarizes some key subfleet characteristics drawn from the survey, for both directly operated and purchased transportation fleets.

DESCRIPTIVE STATISTICS SUBFLEETS	Fixed-Route, Directly Operated Fleets	Fixed-Route Purchased Transportation (Contracted) Fleets
# of Fleets	113	33
Total Number of Subfleets	345	86
Average (Mean) Number of Subfleets per Fleet	3.1	2.6
Median # of Subfleets per Fleet	3.0	2.0
Highest Number of Subfleets in a Fleet	8	5
Lowest Number of Subfleets in a Fleet	1	1

The responding transit agencies had, on average, 3.1 different subfleets within their *directly-operated* fixed-route fleet, and 2.6 different subfleets in their *purchased transportation* fleet. The variance within each distribution is quite wide, with half of the 113 *directly-operated* fleets having more than 3 subfleets, and half having fewer than 3. *Purchased transportation* fleets had a lower median, with half of the 33 fleets having more than 2 subfleets and half having fewer than 2.

The following tables below highlight the numbers and percentages of subfleets and vehicles available for maximum service (VAMS) for each bus size and type. The first table summarizes the surveyed *directly-operated* fleets, while next table focuses on *purchased transportation* fleets.

DISTRIBUTION OF SUBFLEETS AND VEHICLES AVAILABLE FOR MAXIMUM SERVICE BY BUS TYPE
FIXED-ROUTE, DIRECTLY OPERATED FLEETS

SUBFLEET Bus Size/Type	Number of Directly Operated Subfleets	Percentage of Total Directly Operated Fleets	Total Number of VAMS in Directly Operated Subfleets	Percentage of Total Number of VAMS in Directly Operated Subfleets
40-foot Standard Bus	92	81%	26,549	73.0%
30-foot Bus	70	62%	1,615	4.4%
35-foot Standard Bus	67	59%	1,476	4.1%
Less than 30-foot Bus	43	38%	927	2.6%
60-foot Standard Articulated Bus	28	25%	2,858	7.9%
Over-the-Road (3-Axle) Bus	19	17%	1,449	4.0%
Rubber-Tired Trolley Replica	7	6%	68	0.2%
40-foot Electric Trolley Bus	5	4%	605	1.7%
40-Suburban Commuter Bus (2-Axle)	4	3%	134	0.4%
60-foot Electric Trolley Bus	3	3%	172	0.5%
45-foot Bus (not Over-the-Road)	2	2%	380	1.0%
Double-Decker Bus	2	2%	63	0.2%
35-foot Mountain Grade Bus	1	1%	38	0.1%
40-BRT Bus	1	1%	10	0.0%
60-foot BRT Articulated Bus	1	1%	6	0.0%

DISTRIBUTION OF SUBFLEETS AND VEHICLES AVAILABLE FOR MAXIMUM SERVICE (VAMS) BY BUS TYPE FIXED-ROUTE, PURCHASED TRANSPORTATION FLEETS

SUBFLEET: Bus Size/Type	Number of Purchased Transportation Subfleets	Percentage of Total Purchased Transportation Fleets	Total Number of VAMS in Purchased Transportation Subfleets	Percentage of Total Number VAMS in Purchased Transportation Subfleets
Less than 30-foot Bus	20	60.6%	452	12.9%
40-foot Standard Bus	19	57.6%	1,946	15.4%
30-foot Bus	17	51.5%	285	8.1%
35-foot Standard Bus	9	27.3%	143	4.1%
Over-the-Road (3-Axle) Bus	7	21.2%	202	5.7%
60-foot Standard Articulated Bus	5	15.2%	315	9.0%
Rubber-Tired Trolley Replica	2	6.1%	16	0.5%
40-Suburban Commuter Bus (2-Axle)	2	6.1%	99	2.8%
45-foot Bus (not Over-the-Road)	2	6.1%	56	1.6%

For *directly-operated* transit fleets, the *40-foot standard bus* continues to be the predominant subfleet. Among all reported *directly-operated* agency fleets, 81.4% had *40-foot standard bus* subfleets. While this is the case, *directly-operated* fleets also reflected significant percentages having a *30-foot bus* subfleet (62%); a *35-foot bus* subfleet (59%); a *less than 30-foot bus* subfleet (38%); and/or a *60-foot standard articulated bus* subfleets (25%). Among all *purchased transportation* transit fleets, 57.6% reported having a *40-foot standard bus* subfleet, exceeded only by those having a *Less-than-30-foot Bus* subfleet (60.6%).

The following table provides some descriptive statistics regarding fleet age (in years) by six of the most common subfleets, as drawn from the survey for directly-operated fleets.

By Bus Size/Type Subfleet	Subfleet Count	MEAN Average Age	MEDIAN Average Age	HIGHEST Average Age	LOWEST Average Age	Percentage of Buses Averaging 8 years Old or Older by Subfleet
Less-than-30-foot Bus	43	5.1	4.5	13	0.1	19%
30-foot Bus	68	7.4	7.4	22.0	0	37%
35-foot Bus	64	7.6	7.0	25.0	1.0	39%
40-foot Standard Bus	90	7.7	7.6	17	1.2	37%
Over-the-Road (3-axle) bus	19	7.8	7.0	22	3	32%
60-foot Standard Articulated Bus	29	5.8	6.0	11	0.7	21%

For surveyed *directly-operated* fleets, the *less-than-30-foot Bus* and *60-foot Standard Articulated Bus* subfleets had the lowest average age and lowest percentage of buses 8 years or older by subfleet. The surveyed *30-foot Bus, 35-foot Bus, 40-foot Standard Bus*, and *Over-the-Road (3-Axle) Bus* subfleets were all very similar in age characteristics; all show means and medians between 7.0 and 7.9 years with 32-39% of the subfleets having an average age of 8 years old or older.

At the subfleet level, there was an opportunity to test the strength of the relationship between the number of spare buses in a subfleet and the average age of that subfleet. A correlation analysis was performed using survey data for six of the most common subfleets among the *directly-operated* fleet survey responses. As described earlier previously, this analysis involved calculating "Coefficients of Determination" (or "R-squared") for the subfleet values for Spare Bus and Average Age variables. The table below summarizes the results.

By Bus Size/Type Subfleet	R-squared: Average Age of Subfleet and Spare Buses in Subfleet
Less than 30-foot Bus	.02
30-foot Bus	<.01
35-foot Standard Bus	<.01
40-foot Standard Bus	<.01
Over-the-Road (3-Axle) Bus	.03
60' foot Standard Articulated Bus	<.01

FINDINGS

On average, over one-third of the five subfleets described above (*30-foot Bus, 35-foot Bus, 40-foot Standard Bus, and Over-the-Road (3-Axle) Bus*) have surpassed "middle age," as have one-fifth of the *less-than-30-foot bus* subfleets with a shorter life cycle. This may reflect a trend of an increasing level of maintenance time required and with resulting vehicle downtime. During this downtime, an adequate number of spare buses must be available to protect the services delivered to the public.

As reflected in the table above, the strength of the relationship between the subfleet variables of Average Age and Spare Buses is virtually non-existent for all six of the subfleets tested. In other words, there appears to be no correlation whatsoever between the number of spare buses in an agency's subfleet and the average age of the buses in that subfleet. This appears to be counter-intuitive since, generally speaking, the older a bus gets the greater the level of maintenance effort required and the need for spare buses to cover for vehicle downtime. It should be noted that this particular rest for correlation test was based upon a relatively small sub-sample size. This may be an area for further exploration in future research.

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2. Subfleet Spare Ratios

The tables below summarize the computed spare ratios for each subfleet based upon the data provided by survey respondents, for both d*irectly-operated* and *purchased transportation* fleets. Each table tabulates the number (and percentages) of subfleets (by bus size/type) whose spare ratios are less than or equal to, or greater than 20%.

NUMBERS OF SUBFLEET SPARE RATIOS BY BUS TYPE
FIXED-ROUTE, DIRECTLY OPERATED FLEETS

Bus/Size Type	# of Subfleet Spare Ratios < or = 20%	# of Subfleet Spare Ratios > 20%	# of Subfleet Spare Ratios > 25%	# of Subfleet Spare Ratios > 30%		Pctg. of Subfleet Spare Ratios < or = 20%	Pctg. of Subfleet Spare Ratios > 20%
45' Bus (not Over-the-Road)	2	0	0	0		100%	0%
35' Mountain Grade Bus	1	0	0	0		100%	0%
Over-the-Road (3-Axle) Bus	15	4	2	2		79%	21%
60' foot Standard Articulated Bus	16	12	7	4		57%	43%
Rubber-Tired Trolley Replica	4	3	3	3		57%	43%
40' Standard Bus	49	39	13	9		56%	44%
35' foot Std. Bus	35	28	15	14		56%	44%

NUMBERS OF SUBFLEET SPARE RATIOS BY BUS TYPE
FIXED-ROUTE, DIRECTLY OPERATED FLEETS (continued)

	# of Subfleet Spare Ratios < or = 20%	# of Subfleet Spare Ratios > 20%	# of Subfleet Spare Ratios > 25%	# of Subfleet Spare Ratios > 30%		Pctg. of Subfleet Spare Ratios < or = 20%	Pctg. of Subfleet Spare Ratios > 20%
Double-Decker Bus	1	1	0	0		50%	50%
30' Bus	29	36	32	30		45%	55%
Less than 30' Bus	16	27	25	19		37%	63%
40' Suburban Commuter Bus (1-Axle)	1	3	2	0		25%	75%
40' Electric Trolley Bus	1	4	3	2		20%	80%
60' Electric Trolley Bus	0	3	2	1		0%	100%
40' BRT Bus	0	1	0	0		0%	100%
60' BRT Articulated Bus	0	1	1	1		0%	100%

NUMBERS OF SUBFLEET SPARE RATIOS BY BUS TYPE
FIXED-ROUTE, PURCHASED TRANSPORTATION FLEETS

	# of Subfleet Spare Ratios < or = 20%	# of Subfleet Spare Ratios > 20%	# of Subfleet Spare Ratios > 25%	# of Subfleet Spare Ratios > 30%		Pctg. of Subfleet Spare Ratios < or = 20%	Pctg. of Subfleet Spare Ratios > 20%
40' Suburban Commuter Bus (1-Axle)	2	0	0	0		100%	0%
45' Bus (not Over-the-Road)	1	0	0	0		100%	0%
Over-the-Road (3-Axle) Bus	6	1	0	0		86%	14%
60' foot Standard Articulated Bus	3	2	0	0		60%	40%
30' Bus	8	8	6	6		50%	50%
40' Standard Bus	8	11	7	7		42%	58%
Less than 30' Bus	6	14	8	7		30%	70%
35' foot Standard Bus	3	7	7	6		30%	70%
Rubber-Tired Trolley Replica	0	2	2	2		0%	100%

The following tables summarize the response to the survey question," Do the Active Vehicles Available for Maximum Service (VAMS) previously specified for this SUBFLEET provide a sufficient number of spare buses to repair, maintain (including preventive maintenance), service, and fuel this SUBFLEET and meet daily operational requirements?"

DIRECT OPERATION	**Are Number of VAMS in this Subfleet Sufficient to Meet Daily Requirements**		
	YES	NO	TOTAL RESPONDING TO QUESTION
40-foot Standard Bus	75%	25%	92
30-foot Bus	77%	23%	69
35-foot Standard Bus	72%	28%	65
Less than 30-foot Bus	66%	34%	44
60-foot Standard Articulated Bus	81%	19%	31
Over-the-Road (3-Axle) Bus	72%	28%	18
Rubber-Tired Trolley Replica	57%	43%	7
40-foot Electric Trolley Bus	100%	0%	5
40-Suburban Commuter Bus (1-Axle)	50%	50%	4
60-foot Electric Trolley Bus	100%	0%	3
45-foot Bus (non Over-the-Road)	50%	50%	2
Double-Decker Bus	100%	0%	2
35-foot Mountain Grade Bus	0%	100%	1
40-BRT Bus	0%	100%	1
60-foot BRT Articulated Bus	100%	0%	1

PURCHASED TRANSPORTATION	**Are Number of VAMS in this Subfleet Sufficient to Meet Daily Requirements?**		
	YES	NO	TOTAL RESPONDING TO QUESTION
40-foot Standard Bus	74%	26%	19
30-foot Bus	76%	24%	17
35-foot Standard Bus	67%	33%	9
Less than 30-foot Bus	76%	24%	21
60-foot Standard Articulated Bus	50%	50%	4
Over-the-Road (3-Axle) Bus	62%	38%	8
Rubber-Tired Trolley Replica	100%	0%	3
40-Suburban Commuter Bus (1-Axle)	50%	50%	2
45-foot Bus (non Over-the-Road)	0%	100%	1

The majority of respondents in virtually all subfleet categories indicated that their VAMS for each of the respective subfleets in their fleet was sufficient to meet daily requirements (given that the subfleet spare ratio may exceed 20%).

FINDINGS

In analyzing the tables above, there is a significant number of agency fleets that have subfleets exceeding a 20% spare ratio. *This is most acute in the 30-foot bus and less-than-30-foot bus subfleet category,* however, there are also a large number of 35-foot, 40-foot, and 60-foot articulated bus subfleets that exceed 20%. Following are the most noteworthy examples of the very high percentages of subfleets that are in excess of 20%:

- For all 43 reported *Less-than-30-foot Bus* subfleets, 37% had a spare ratio that was less than or equal to 20%, however 63% had spare ratios that exceeded 20%--with 44% having subfleet spare ratios exceeding 30%.

- For all 65 reported *30-foot Bus* subfleets, 45% had a spare ratio that was less than or equal to 20%, however 55% had spare ratios that exceeded 20%--with 46% having subfleet spare ratios exceeding 30%.

- For all 63 reported *35-foot Bus* subfleets, 56% had a spare ratio that was less than or equal to 20%, however 44% had spare ratios that exceeded 20%--with 22% having subfleet spare ratios exceeding 30%.

- For all 88 reported *40-foot Standard Bus* subfleets, 56% had a spare ratio that was less than or equal to 20%, however 44% had spare ratios that exceeded 20%--with 10% having subfleet spare ratios exceeding 30%.

- For all 28 reported *60-foot Standard Articulated Bus* subfleets, 57% had a spare ratio that was less than or equal to 20%, however 43% had spare ratios that exceeded 20%--with 14% having subfleet spare ratios exceeding 30%.

There are similar examples among the survey *purchased transportation* fleets and subfleets as depicted in the table above.

Where an agency has one or more subfleets that exceed 20%, it must reduce the number of spare buses below 20% in its remaining subfleets in order to come in below the fleet-wide guideline of 20%. This may or may not be feasible without adverse maintenance, operational, or service quality implications.

Following are a range of comments from survey respondents:

> *"Because of the technical and operational reasons mentioned, our 40-foot bus fleet is also over the allowable 20% spare ratio rule. Since we only have six 30-foot buses, if there are not enough buses to meet the daily requirement, we would deploy 40-foot buses to meet the operational requirement. This in turn lowers available spares (on 40-foot buses) for that day's commitment."*

> *"Given this subfleet quantity is calculated in the overall spare ratio, for every one of these buses on hand over the 20% spare ratio, it reduces on a one for one basis the number of spare 40' buses we can have on hand and available for service. Looking at peak requirements of 11 (smaller buses) vs. 183 (40' buses) the offset is extremely disproportionate and adversely impacts our support of the larger fleet's revenue service requirements."*

> *"No (problem achieving the 20% guideline) because we currently only operate 30-foot and 40-foot buses. Future plans for growth and different types of buses to meet passenger and services demands will constitute the purchase of 60-foot articulate buses in the fleet. They will also need to have a spare ratio conducive to the technology and operational demands. Branding buses differently to meet BRT obligations further exacerbate the spare ratio problems as you need spare buses for this "second" fleet of equipment."*

3. Fuel/Energy Propulsion Systems

The following tables summarize the mean, median, highest number, and lowest number of *Fuel/Energy Propulsion Systems* and *Fuel/Energy System Subfleets* for both *directly-operated* and *purchased transportation* fleets reported. To illustrate the distinction, if an agency had a *directly operated* bus fleet powered by Diesel, CNG, and Hybrid-Electric (Diesel), it would be reflected in the survey that it had three (3) Fuel/Energy systems. If that same agency fleet had both 35-foot and 40-foot diesel buses; 30-foot CNG buses; and both 60-foot and Over-the-Road Articulated Hybrid-Electric Buses, it would be reflected in the survey as four (4) Fuel/Energy System Subfleets. The intent is to assess the level fleet complexity that comes with operating and maintaining not only buses with different fuel/energy systems, but also different bus sizes and types within the same fleet.

DIRECTLY-OPERATED FLEETS

	Number of Fuel/Energy Propulsion Systems	**Number of Fuel/Energy System Subfleets**
# of Fleets Reported for the Question	101	101
Average (Mean)	1.8	3.5
Median	2.0	4.0
Highest Number	5	8
Lowest Number	1	1

PURCHASED-TRANSPORTATION FLEETS

	Number of Fuel/Energy Propulsion Systems	**Number of Fuel/Energy System Subfleets**
# of Fleets Reporting on the Question	28	28
Average (Mean)	1.8	3.1
Median	1.5	3.0
Highest Number	4	8
Lowest Number	1	1

The tables below summarize depict the number of agencies with each Fuel/Energy Type and the number of buses reported in each category, for both *directly-operated* and *purchased transportation* fleets.

DIRECTLY-OPERATED FLEETS

FUEL/ENERGY SYSTEM TYPE	Number of Agencies with each Type	Pctg. of Reporting Agencies		Number of Buses of with each Type	Pctg. of All Reported Buses
Gasoline	11	11%		121	<1%
Diesel	100	99%		25,388	77%
CNG	20	20%		4,842	15%
LNG	1	1%		228	<1%
Propane	2	2%		22	<1%
Hybrid-Electric (Gasoline)	8	8%		76	<1%
Hybrid-Electric (Diesel)	35	35%		2,083	6%
Hybrid-Electric (CNG)	1	1%		1	<1%
Overhead-Electric (Trolley Bus)	6	6%		804	2%
Fuel Cell	2	2%		4	<1%

PURCHASED-TRANSPORTATION FLEETS

FUEL/ENERGY SYSTEM TYPE	Number of Agencies with each Type	Pct. of Reporting Agencies		Number of Buses with each Type	Pct. of All Reported Buses
Gasoline	8	28%		150	6%
Diesel	27	96%		1,284	53%
CNG	9	32%		546	22%
LNG	1	4%		354	14%
Propane	3	11%		56	3%
Hybrid-Electric (Gasoline)	0	0%		0	0%
Hybrid-Electric (Diesel)	2	7%		51	2%
Hybrid-Electric (CNG)	0	0%		0	0%
Overhead-Electric	0	0%		0	0%
Fuel Cell	0	0%		0	0%

FINDINGS

With 101 responses, the average *directly-operated* bus fleet has nearly two (1.8) fuel/energy systems to manage in its daily maintenance and operation. The median number of fuel/energy systems is 2.0, meaning 50% of all *directly-operated* Bus fleets have more than 2 fuel/energy systems (and as many as 5), and 50% have fewer than 2 (and as few as 1). Add into this the number of fuel/energy system s*ubfleets* and the average goes up to 3.5 with a median of 4. The number of fuel/energy system s*ubfleets* were reported as high as 8 and as few as 1. The 28 Purchased Transportation fleet responses had very similar results.

The other table clearly points to the continued dominance of the diesel engine as a bus propulsion system; 99% of agencies with *directly-operated* fleets indicated that they operated diesel buses. Diesel accounted for 77% of all *directly-operated* buses reported in the survey. Hybrid-Electric (Diesel) Buses were reported by 35% of these agencies (with 6% of the buses). Compressed Natural Gas (CNG) was listed in 20% of the *directly-operated* fleets (with 15% of the buses). *Purchased transportation* fleets were also dominated by diesel, followed by CNG.

Despite the dominance of *diesel*, the survey results reflected a wide array of other fuel/energy technologies in their fleets. Many of those systems are not nearly as reliable as *diesel*, although they have been purchased for other reasons such as clean air benefits.

The fuel/energy system survey data clearly demonstrates the significant complexity that transit systems in the U.S. and Canada deal with in their fleet maintenance and management. Below are some of the comments from survey respondents:

> *"Occasionally these buses require extensive maintenance because of the complicated and technical requirements of the fuel system (CNG) and engine. Parts for these engines (and fuel system) are expensive and can prevent these vehicles from entering service due to the length of time it sometimes takes for specific parts. As stated, over the last twenty years the "transit bus" has tremendously evolved and currently, modern-day technically advanced buses are considered one of the most highly advanced operational-technical equipment on the road. They are complex, house many sub-systems inherent to providing public transit vehicle services that is safe and reliable. The various complexities add to down times, with parts attainment and advanced repair procedures adding to the duty cycle of the vehicle."*
>
> *"(We) have 62 gasoline hybrid coaches that are new technology and are unreliable. An old technology diesel coach has standard 90 - 92% reliability, while a gasoline hybrid has less than 80% reliability (counting all unplanned work). The majority of the difference has to do with the propulsion system (inverters, ultracapacitors, engines, PLC system etc...). These coaches are relatively new (3.2 years) and they are having tons of problems. In the past, a new diesel had hardly any failures during the first 4 years of life. Note: the newer diesels (starting with 2003) with the upgraded emission systems are starting to have lower reliability."*
>
> *"These 30 hybrid coaches have been experiencing an abnormal number of failures i.e. fuel transfer pumps, traction batteries, air compressors, door sensors, etc. While there is warranty support the coaches are still required to be removed from service while this repair activity takes place. These fleet defects have also been detrimental to vehicle reliability in this fleet, these critical systems have failed with such regularity as to cause repeated road calls and a resultant decrease in MDBF. Long lead times, increased demand from the parts manufacturer with no alternate vendors available means a higher spare ratio is needed just to be sure we can put the correct number of coaches into the field each day. Without a spare ratio higher than the normal, 20% maintenance and passenger service would suffer."*

In short, the complexity of today's Fuel/Energy systems has a clear impact on agency spare bus needs. While not the case for every transit organization, for many agencies this complexity appears to challenge their ability to maintain a 20% overall fleet spare ratio.

4. On-Board Advanced Technology Systems

The following tables depict the average, median, highest number, and lowest number of on-board advanced technology systems per agency, as well as the prevalence of the various advanced technology systems among organizations responding to the survey.

On-Board Advanced Technology Systems	Combined Directly Operated and Purchased Transportation Fleets
# of Agencies Reporting on the Question	129
Average # of Advanced Technology Systems	6.4
Median # of Advanced Technology Systems	6.0
Highest Number of Technology Systems	12
Lowest Number of Technology Systems	1

On-Board Technologies	Number of Agencies with Each Technology	Pctg. of Total (129) Survey Respondents
Electronic Head Signs	111	86%
On-Board Video Surveillance	97	75%
Electronic Fare Collection	93	72%
Digital Radio	83	64%
Automatic Vehicle Locator	69	53%
Advanced Emission Controls	68	53%
Bus Stop Enunciation	66	51%
Automated Passenger Counters	56	43%
Data Transmission	55	43%
Regenerative Braking	50	39%
Hazard Detection	24	19%
Remote Diagnostics	21	16%
Wireless Internet (WiFi)	14	11%
Closed Area Networks	10	8%
None of the Above	3	2%

In addition, the following other fleet technologies were reported by respondents:

Auxiliary Starting Aid/Capacitor	Multiplex
Pre-heaters	Emergency Notification System
Fire Suppression System	Fuel Management System
"NextBus"	Advanced Interior Lighting--LED Plug-In
Hydraulic brake retarders for normal service area	High Output HVAC
"Jake Brakes" for long mountain descents	Automated Fueling
Low-Emission Engine Testing	Acoustic Door-Control Sensors
Transit Television Network (TTN)	Passenger Counting through the Mobile Data Terminals
Forward Facing Transit-Only Lane Enforcement Cameras	

There are many reasons why transit agencies introduce the new technologies, as outlined in the table below:

Reasons for Implementing On-Board Technologies	Number of Agencies with Each Reason	Pctg. Of Total (129) Survey Respondents
Safety Enhancement	100	78%
Improved Efficiency	96	74%
Customer Comfort and/or Convenience	89	69%
Compliance with External Directives	86	67%
Environmental Benefits	73	57%
Customer Demand	65	50%
Marketing Benefits	53	41%
Reduced Operating and/or Maintenance costs	47	36%
None of the Above	4	3%

In addition, the following other reasons were reported by respondents:

Tracking and Improved Monitoring	Better understanding of system demand
ADA Compliance	Data gathering
Better accuracy in reporting	Improved communications
Security enhancements	Easier starting in winter months
Capture passenger boarding data	Damage recovery
Gain information to aid driver training	Better management info. and control

While the new technologies have many benefits, the following table summarizes the responses from survey participants concerning the impacts of advanced technologies in their fleets on keeping within a 20% spare ratio.

Has the addition of these advanced technologies affected your ability to keep your entire active fleet within the 20% Spare Ratio Standard? (of 129 Respondents)					
# YES	Percent YES	# NO	Percent NO	# No Response	Percent No Resp.
49	38%	77	60%	3	2%

FINDINGS

On average, the 129 responding agencies reported having over 6 advanced technology systems in their entire fleet (6.4) with a median of 6.0: one-half of all responding agencies support more than 6 advanced technologies and one-half support fewer than 6. The largest number of advanced technologies at a single agency was 12, with lowest number being 1.

Over 50% of the agencies reported having each of the following complex technologies to support:

- Electronic Head Signs
- On-Board Video Surveillance
- Electronic Fare Collection
- Digital Radio
- Automatic Vehicle Locator
- Advanced Emission Controls
- Bus Stop Enunciation

When asked how these advanced technologies impacted their ability to stay at or below the 20% spare ratio level, 60% of the survey respondents indicated that the introduction of advanced technology systems at their agencies did *not* affect their ability to maintain a 20% spare ratio. However, over one-third of the responding organizations (38%) did express that these systems affected their ability to keep the entire active fleet within a 20% spare ratio.

Following are some of the comments from survey respondents:

> "*New technology buses have multiple electronic subsystems like CAD/AVL, vehicle health monitoring, cameras, automated fueling, ECT. We have also added emission devises and other environmental designed subcomponents. Years ago when the spare ratio was created no specialized electronics or emissions systems were part of bus design and maintenance. The addition of this equipment has burdened the labor resources and facility design to the point where it is very difficult to maintain service requirements.*"

"These sub-systems are now required to keep a coach in service and are very technical - thus requiring specialized technicians to repair them. Many times one system will cause a problem with another (for example, interference of one wireless system (GPS) with another wireless video surveillance system)."

"Each additional item of technology that is added to a vehicle is another item that must be maintained and repaired - thus increasing maintenance time required and therefore reducing vehicle availability, which impacts our ability to support revenue service requirements within the 20% cap."

"With all these enhancements to these coaches there comes an increased level of maintenance and associated cost. Coaches must be kept out of service routinely for vendor maintenance, adjustment or programming. This means added handling, increased storage needs, scheduling, etc. While these systems are in for maintenance other coaches must be use to backfill for them on the line, these new systems maintenance needs are not factored into any spare ratio calculations, as that has not changed from before these systems came into existence."

Even the predominant cleaner diesel technology of today relies on complex emission control systems.

"Some of the advanced technology has proven to be more problematic than it's worth. The advanced emission controls have increased maintenance demands and road call service interruptions. The need to perform frequent engine exhaust regenerations manually cost countless man-hours and equipment to keep vehicles on the road. The original design was for the regenerations to be automatic and virtually invisible to the operator and maintenance. The 20 percent spare ratio in this case is inadequate to keep the line at the desired supply without additional buses. Most other technology items have not been a problem or are not critical and can be worked around."

In summary, the complexity and prevalence of today's Advanced Technology Systems has a strong impact on agency spare bus requirements. While not the case for every transit organization, for many agencies the introduction of advanced technology systems and their complexities has challenged their ability to operate within a 20% spare ratio.

5. Diversity of Manufacturers

The following chart summarizes the survey responses from transit organizations regarding the number of bus manufacturers present with their fleet. It intended to assess the complexity of the fleet and the impact on spare bus needs.

MANUFACTURERS REPRESENTED IN BUS FLEET	**Combined Directly Operated and Purchased Transportation Fleets**
# of Agencies Reporting on the Question	129
Average # of Bus Manufacturers within Fleet	3.6
Median # of Bus Manufacturers within Fleet	4.0
Highest Number of Manufacturers in a Fleet	10
Lowest Number of Manufacturers in a Fleet	1

As described, the average responding transit agency has over 3 different bus manufacturers (3.6) represented in within its overall fleet. With a median of 4.0, one-half of all respondents have more than 4 manufacturers represented in their bus fleet and one-half have fewer than 4. The largest number of manufacturers at a single agency is 10, with the lowest number being 1.

FINDINGS

Although multiple manufacturers in a fleet can mean increased inventory and some maintenance challenges, it does *not* appear that the diversity of manufacturers in and of itself has had a significant impact on the number of spare vehicles required to support service and maintenance needs. Of greater import are the quality and reliability of the specific manufacturer's products used in a particular fleet such as the basic bus and its many major components and systems.

E. Surveyed Service Mix Profile and Interchangeability Issues

This portion of the analysis sought to assess the mix and diversity of service types offered by surveyed transit agencies; identify any bus interchangeability Issues; and determine if the lack of available buses equipped with certain essential Specialized Features affected the ability to meet daily pull-out requirements.

There were 10 primary service type categories that emerged from the survey, including:

- Bus Rapid Transit
- Commuter Express
- Regional Trunk
- Local Route
- Circulator
- Shuttle
- Special Event
- Rail Outage Back-Up
- Emergency

The following table summarizes some key service type characteristics drawn from the survey, for combined *directly- operated* and *purchased transportation* fleets.

TYPES OF SERVICES PROVIDED BY SURVEYED AGENCIES **Combined Directly Operated and Purchased Transportation Fleets**	
# of Agencies Reporting on the Question	129
Average # of Service Types Provided by Agency	3.9
Median # of Service Types Provided by Agency	4.0
Highest Number of Service Types Provided by an Agency	10
Lowest Number of Service Types Provided by an Agency	1

The following table summarizes both the numbers of surveyed agencies operating each type of service and the respective percentage of all survey respondents. For example, 124 of the 129 (96%) survey respondents operate Local Route services, while only 20 agencies out of the 129 (16%) provide Bus Rapid Transit (BRT) service to their customers.

Type of Service	**Number of Agencies Operating That Type of Service**	**Pctg. of Total (129) Survey Respondents**
Local Route	124	96%
Commuter Express	66	51%
Emergency	61	47%
Circulator	56	43%
Shuttle	56	43%
Special Event	55	43%
Rail Outage Back-Up	34	26%
Regional Trunk	32	25%
Bus Rapid Transit (BRT)	20	16%
Other	5	4%

Not all agency buses are able to operate or meet the requirement of every type of service offered. To assess bus interchangeability issues, the following are tables summarizing survey responses for each of 8 specific specialized features that may or may not be available on different types of buses (i.e., in different subfleets):

- High Passenger-Carrying Capacity (more than a 40-foot bus)
- More than One Door
- Special Exterior Branding with Unique Paint (or Wrap) Scheme
- Exterior Wood Trim (e.g., for Trolley Replicas)
- Ability to Maneuver in Confined Areas
- Luggage Racks and Storage
- Premium Seating and other Interior Amenities
- Low Floor

Each table indicates the percentage of agencies that **require** that specific specialized feature in order for a bus to be able operate in each type of service provided.

SPECIALIZED FEATURE: HIGH PASSENGER-CARRYING CAPACITY (more than a 40-foot bus)

Type of Service	Number of Agencies that Require this Feature in order for a Bus to operate in Each Service Type	Number of Agencies that Provide Each Service Type	Percentage Requiring this feature
Bus Rapid Transit (BRT)	12	20	60%
Commuter Express	28	66	42%
Rail Outage Back-Up	10	34	29%
Special Event	14	55	25%
Regional Trunk	8	32	25%
Emergency	11	61	18%
Shuttle	10	56	18%
Local Route	20	124	16%
Circulator	6	56	11%

SPECIALIZED FEATURE: MORE THAN ONE DOOR

Type of Service	Number of Agencies that Require this Feature in order for a Bus to operate in Each Service Type	Number of Agencies that Provide Each Service Type	Percentage Requiring this feature
Bus Rapid Transit (BRT)	13	20	65%
Local Route	70	124	56%
Special Event	29	55	53%
Shuttle	25	56	45%
Rail Outage Back-Up	14	34	41%
Regional Trunk	13	32	41%
Circulator	22	56	39%
Commuter Express	25	66	38%
Emergency	23	61	38%

SPECIALIZED FEATURE: SPECIAL EXTERIOR BRANDING WITH UNIQUE PAINT SCHEME

Type of Service	Number of Agencies that Require this Feature in order for a Bus to operate in Each Service Type	Number of Agencies that Provide Each Service Type	Percentage Requiring this feature
Bus Rapid Transit (BRT)	14	20	70%
Shuttle	17	56	30%
Circulator	15	56	27%
Commuter Express	16	66	24%
Special Event	12	55	22%
Local Route	26	124	21%
Regional Trunk	5	32	16%
Rail Outage Back-Up	4	34	12%
Emergency	4	61	7%

SPECIALIZED FEATURE: EXTERIOR WOOD TRIM (e.g., for Trolley-Replicas)

Type of Service	Number of Agencies that Require this Feature in order for a Bus to operate in Each Service Type	Number of Agencies that Provide Each Service Type	Percentage Requiring this feature
Circulator	5	56	9%
Shuttle	3	56	5%
Special Event	3	55	5%
Bus Rapid Transit (BRT)	1	20	5%
Local Route	4	124	3%
Commuter Express	1	66	2%
Emergency	0	0	0%
Rail Outage Back-Up	0	0	0%
Regional Trunk	0	0	0%

SPECIALIZED FEATURE: ABILITY TO MANEUVER IN CONFINED AREAS

Type of Service	Number of Agencies that Require this Feature in order for a Bus to operate in Each Service Type	Number of Agencies that Provide Each Service Type	Percentage Requiring this feature
Circulator	32	56	57%
Shuttle	26	56	46%
Local Route	48	124	39%
Bus Rapid Transit (BRT)	7	20	35%
Special Event	18	55	33%
Emergency	18	61	30%
Rail Outage Back-Up	9	34	26%
Regional Trunk	7	32	22%
Commuter Express	11	66	17%

SPECIALIZED FEATURE: LUGGAGE RACKS/STORAGE

Type of Service	Number of Agencies that Require this Feature in order for a Bus to operate in Each Service Type	Number of Agencies that Provide Each Service Type	Percentage Requiring this feature
Commuter Express	21	66	32%
Regional Trunk	7	32	22%
Bus Rapid Transit (BRT)	3	20	15%
Special Event	2	55	4%
Local Route	4	124	3%
Rail Outage Back-Up	1	34	3%
Circulator	1	56	2%
Emergency	0	0	0%
Shuttle	0	0	0%

SPECIALIZED FEATURE: PREMIUM SEATING AND OTHER INTERIOR AMENITIES

Type of Service	Number of Agencies that Require this Feature in order for a Bus to operate in Each Service Type	Number of Agencies that Provide Each Service Type	Percentage Requiring this feature
Bus Rapid Transit (BRT)	11	20	55%
Commuter Express	33	66	50%
Regional Trunk	9	32	28%
Special Event	9	55	16%
Circulator	5	56	9%
Shuttle	5	56	9%
Rail Outage Back-Up	3	34	9%
Local Route	10	124	8%
Emergency	3	61	5%

SPECIALIZED FEATURE: LOW FLOOR

Type of Service	Number of Agencies that Require this Feature in order for a Bus to operate in Each Service Type	Number of Agencies that Provide Each Service Type	Percentage Requiring this feature
Bus Rapid Transit (BRT)	16	20	80%
Local Route	65	124	52%
Circulator	23	56	41%
Regional Trunk	12	32	38%
Shuttle	20	56	36%
Special Event	18	55	33%
Commuter Express	19	66	29%
Rail Outage Back-Up	9	34	26%
Emergency	13	61	21%

OTHER ESSENTIAL SPECIALIZED FEATURES REPORTED

Following are some of the other items reported by survey respondents as "must haves" for a bus to operate in each specific service types.

NOTE: It is assumed that all buses on all services require ADA accessibility (lift or ramp) with an adequate number of wheelchair securement stations.

Regional Trunk

- Bicycle racks
- HVAC
- High passenger capacity; not longer than 40 foot bus
- Conventional bus
- Side object detection system
- Highway certificate
- On Spot Chains
- High floor
- One door

Bus Rapid Transit (BRT)

- Bicycle racks
- HVAC
- Left and right side doors
- Bus (Traffic) Signal Priority (BSP)
- Complete Electronics Package
- Exterior aesthetic styling
- Color LED programmable signs
- 3 Doors
- Extra space for standees

Local Route

- Bicycle racks
- Compatible two way radio
- HVAC
- Some 60' coaches needed for passenger loads
- Two - way radio
- Side object detection system
- On-Spot Chains
- Automated announcement system
- Cameras (on-board surveillance)

Commuter Express

- Bicycle racks (for 4)
- High horsepower-to-weight ratio for hill climbing
- On-board Wi-Fi access
- Climate control system
- Latest technology in lighting and signage
- Ability to provide comfortable, quiet travel at highway speed
- High passenger capacity - not longer than 40-foot
- Engine w/larger HP
- Seat-back, tray tables
- High horsepower engine
- "Jake" brakes

Shuttle

- HVAC
- Mobile data terminals
- Side object detection system
- Special announcement capability
- Two-Way Radio
- Bicycle rack
- Cameras

Special Event

- Alternative fuel
- Two - way radio
- Mud and snow tires, fog lights, ski racks, and tire chains for mountain service
- High horsepower for steep grades
- Extra space for standees

Emergency

- HVAC
- High passenger capacity, not longer than 40 foot
- Two - way radio

Circulator

- Bicycle Rack
- HVAC
- Short buses
- Side object detection system
- Two-way radio

The following table summarizes the responses from survey participants concerning the impacts of the lack of essential Specialized Bus Features on meeting the daily service assignments.

Has the lack of available buses equipped with these essential Specialized Features affected your ability to meet daily pull-out requirements of any of your services? (89 responded to the question).			
# YES	Percent YES	# NO	Percent NO
21	24%	68	76%

FINDINGS

U.S. and Canadian transit systems deliver a wide range and diverse mix of services to the public. Local Route service is the clearly the predominant service type, offered by 96% of the surveyed respondents. However, between 43% and 51 % of surveyed agencies also provide Commuter Express, Emergency, Circulator, Shuttle, and Special Event services. Continuing to emerge as a cost-effective, high-capacity transit solution, Bus Rapid Transit (BRT) service is offered by 16% of those agencies responding to the survey.

Each transit organization, on average, provides about 4 different types of service. With a median of 4.0, one-half of all agencies offer more than 4 service types and one-half provide fewer. The largest number of service types reported by an agency was 10, with the smallest number being 1.

Each service type has its own unique operating characteristics, maintenance demands, and, in many case, specialized vehicle and accessory requirements. Consequently, to fully meet the needs of the range of service types offered by each agency, the spare ratio must be sufficient within the subfleet(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. Following are some of the major requirements that can govern and limit the interchangeable use of certain spare buses.

The survey found that in order to deliver ***Bus Rapid Transit*** service, a bus assigned to that service MUST have the following specialized features:

- Low-Floor (reported by 80% of respondents that offer that service)
- Special Exterior Branding with Unique Paint (or Wrap) Scheme (by 70%)
- More than One-Door (by 65%)
- High-Passenger Carrying Capacity (by 60%)
- Premium Seating and Other Interior Amenities (by 55%)

The survey found that in order to deliver ***Commuter Express*** service, a bus assigned to that service MUST have the following specialized features:

- Premium Seating and Other Interior Amenities (reported by 50% of respondents that offer that service)
- High-Passenger Carrying Capacity (by 42%)
- More than One-Door (by 38%)
- Luggage Racks and Storage (by 32%)

The survey found that in order to deliver ***Regional Trunk*** service, a bus assigned to that service MUST have the following specialized features:

- More than One-Door (reported by 41% of respondents that offer that service)
- Low-Floor (by 38%)
- Premium Seating and Other Interior Amenities (by 28%)

The survey found that in order to deliver ***Local Route*** service, a bus assigned to that service MUST have the following specialized features:

- More than One-Door (reported by 56% of respondents that offer that service)
- Low-Floor (by 52%)
- Ability to Maneuver in Confined Areas (by 39%)

The survey found that in order to deliver ***Circulator*** service, a bus assigned to that service MUST have the following specialized features:

- Ability to Maneuver in Confined Areas (reported by 57% of respondents that offer that service)
- Low-Floor (by 41%)
- More than One-Door (by 39%)
- Special Exterior Branding with Unique Paint (or Wrap) Scheme (by 27%)

The survey found that in order to deliver ***Shuttle*** service, a bus assigned to that service MUST have the following specialized features:

- Ability to Maneuver in Confined Areas (reported by 46% of respondents that offer that service)
- More than One-Door (by 45%)
- Low-Floor (by 36%)
- Special Exterior Branding with Unique Paint (or Wrap) Scheme (by 30%)

Of the 89 responding to the question, "*Has the lack of available buses equipped with these essential Specialized Features affected your ability to meet daily pull-out requirements of any of your services?,"* 76% indicated "NO," and 24% reported "YES." The lack of having the "right" bus available to meet their specific service needs does not appear to be a problem for three-quarters of those agencies responding to the question. Conversely, the lack of having the appropriate bus available *does* impact the ability of one-quarter of the respondents to meet their daily pull-out requirements--though a minority, still a significant proportion.

Following are some comments from those survey respondents that indicated "YES" on the question above:

> *"HVAC is required to be operable on every bus placed into passenger service. Buses with non-functioning air conditioning are not placed into service or removed from service and replaced if possible during the months of April through November. Air conditioning during the period noted above is an employee/passenger life safety requirement. We're in Arizona...high temperatures can reach 115 degrees."*
>
> *"Occasionally it is a problem."*
>
> *"The special branded shuttle buses. They are a problem bus to begin with - very unreliable. We have to have extras in each brand type to insure the number needed for their peak requirement."*
>
> *"Even with a spare ratio exceeding 20% for the BRT Fleet, it has been a challenge to maintain a minimum of 10 buses available for peak schedule requirements. These buses have special branding and are not used on traditional local routes."*
>
> *"With our circulator service in the downtown, if a 30' coach is not available, we miss service. We cannot substitute our 30' coaches with any other coaches."*
>
> *"When 60' buses not available, substituting 40' buses reduces capacity."*

F. Surveyed Maintenance Program Challenges

This section assesses the Maintenance Program challenges and practices, analyzing and summarizing the responses to the project survey. The following table summarizes survey responses relative to the need for mechanics defines as the difference between positions required and positions budgeted.

Mechanic Requirements

For All 129 Responding Agencies	
Total Mechanics/Techs Required	12,354
Total Mechanics/Techs Budgeted	12,234
Total Net Difference	-120
Pctg. of agencies **not** needing more mechanics budgeted (Net greater than or equal to 0)	73%
Pctg. of agencies needing more mechanics budgeted (Net Less than 0)	21%
Largest Agency Net Need of budgeted mechanic positions	-32
Pctg. of agencies with no response	6%

The essay responses were very thoughtful and varied. Following is a summary of the 129 responses by category:

Categorized Essay Responses to the Survey Question: "What, if any, challenges has your organization experienced in Attracting, Retaining, and Training qualified mechanics/technicians?

CATEGORIES	**Number of Response**	**Percent of Total**
Finding Experienced Mechanics	39	30%
Insufficient Pay	20	16%
Bad Hours/Days/Job Progression	9	7%
Lack Of Aptitude for Training	2	1%
Training Issues	9	7%
Hiring Freeze	2	2%
No Problem	17	13%
Contracted	3	2%
N/A or Blank	28	22%
TOTAL	129	100%

Following are several of the essay responses themselves:

"Technician training is a challenge keeping up with technology advancements."

"Our progression from Class C to Class B to Class A mechanic, over a 7 year period, does seem to provide ample time for inexperienced mechanics to gain necessary experience. Our mechanic turnover rate is very low. No particular unmet challenges."

"Past labor market conditions have required our organization to recruit across North America as well as abroad."

"The industry is suffering from major shortfalls in journeymen technicians who can repair advanced technology systems. Every property across the US is experiencing shortages in qualified technicians who possess the vast experience required of these advanced technological systems. This has created new strategies in the hiring, training and retention of employees. Many transit properties train and "breed" their own technicians thereby providing advanced technical instruction and bringing these employees forward as they gain valuable and necessary experience. The shortfall in qualified journeyman technicians creates maintenance repair problems to properly and effectively maintain these assets. As continual changes in technology advance, the capacity to hire experienced employees in the future is austere, and it will definitely impact the ability to provide reliable vehicles which must meet the ever-changing operational requirements. This is considered another strong reason for changing the spare ratio away from "20%."

"The availability of experienced mechanics is at a point where it is difficult to find new employees. Although we pay premium salaries and benefits, the pool of qualified applicants is drying up. Once we find a qualified employee there is an extensive training program that we must undertake to make a general mechanic functional in a transit environment. The systems on a coach are both advanced and in some cases unique. As we install more and more required or desired equipment, this learning curve steepens. Once hired and trained, we have no issue with employee retention."

"This is a huge problem. Mechanics/Technicians now need both to get dirty wrench-turning, but also have to be computer literate. It used to be you learned fairly quickly on the job. The learning curve is much longer. We have had our own apprentice program to help solve the problem but it is a continuing challenge to find or grow good Technicians. Many people don't want to work a second or third shift. Many don't like the Union seniority system which limits what work they do in their early years on the job. We have to provide a lot more training which in turn takes mechanics/technicians away from their repair work. Every time we get a new bus there is a huge training requirement."

"As in most all transit systems across the country, finding and hiring good diesel mechanics is a never ending process. Most young guys want to work with much cleaner equipment such as computers instead of dirty diesel engines and transmissions. Coordinating and working with technical training centers and local colleges provides the odd apprentice but on the whole these types of mechanics are a rare breed. Attracting mechanics for the evening and night shifts and weekend duty is a constant problem because everybody wants to work the day shift Monday through Friday. Nothing has changed in this arena in the past few years except the size of the dwindling pool of potential mechanics."

"Finding qualified technicians with previous CNG experience is the most significant challenge. This challenge is mitigated with our training program that is designed to bring new technicians up to speed quickly."

"Challenge #1: Paid/days off, due the senior structures of our shop a new hire would start on the graveyard shift. Most potential hires will not work the shift hours. Most heavy equipment repair facilities in the area starting pay is eight to ten dollars an hour more, than my starting pay. Challenge #2: Last year's recruitment for mechanics was open for six months; we received only twenty applications, and out of the twenty, only eight met the minimum requirements. It is a nightmare, the problem a small pool of qualified folks and a smaller number of young people that are moving in to the trade."

"When the economy was hot we had some problems getting qualified candidates. It was also hard to attract people to work graveyard shift as a new employee. The current economy has many applicants. We feel it we can get a person to stay here for 5 years they will have accrued enough sick leave, vacation and retirement to see the benefit of making a career investment. We stress that with new employees to encourage them to look beyond their paycheck. We also have two in-house apprentice programs that have produced some excellent technicians."

"We have found a growing lack of qualified new mechanics that have the ability to start and do the work with minimum training. So, we have had to start our own in-house training program. With that program, comes the issue of trying to find adequate time to dedicate to the training. Also, keeping all the mechanics, new and seasoned, trained up on all of the changing technologies, including emission standards (is a challenge). We have also had problem with keeping qualified people willing to work on the night shifts."

"Training technicians to learn new technology is the biggest challenge. Most of our older mechanics are used to mechanical system and have no incentives to learn the new technology. Today we have to teach computers for diagnostics and electronics. The old days or replacing parts is gone. Our second major issue has to do with the lack of material and standard procedures for new technology. Most technology is sold on what it can do for us and the maintenance (being new technology) is an unknown. We all know that technology changes fast, but we have to keep everything operational for the minimum life of the coach (12 years). One last issue has to do with recruitment of new technicians. If you hire in new techs with electronic skills, they don't want to stay long because of the heavy-duty nature of the work. It is dirty and hard. Least senior mechanic has to do the heavy grunt work. If you hire an old skilled mechanic, they are not able to do any technical work."

"Attracting and retaining mechanics is a non issue. Training mechanics from the street to the transit industry is an ongoing process. Our training department is small, with limited resources. They focus on new hire classes and technical support to the operating divisions, leaving limited time for developmental classes for the work force. Specialized skill training such as Hybrid components and new technologies has been difficult."

"Due to the economic downturn and increased ridership, our ability to attract and retain qualified candidates has been on the rise. We have has initiated an apprenticeship program to provide advanced training for entry and mid-level mechanics. Screening prospective candidates has become more of a challenge."

Following is a summary table concerning the number of shifts operated at the survey respondent maintenance facilities.

Maintenance Shifts

For All 129 Responding Agencies	
Average Number of Maintenance Shifts Operated	2.6
Percentage running 3 or more shifts	62%
Percentage running 2 to 2.5 shifts	26%
Percentage running 1 shift	7%
Not Applicable or No Response	5%

Mid-Life Scheduled Overhaul Program

Following is a summary table concerning the number of responding agencies that have mid-life scheduled overhaul components.

Does your organization have a mid-life scheduled overhaul program for major components? (of 129 respondents)					
# YES	Percent YES	# NO	Percent NO	# No Response	Percent No Resp.
41	32%	84	65%	3	2%

Scheduled Component Change-Out Program

Following is a summary table concerning the number of responding agencies that have scheduled components change-out programs.

Does your organization have a Scheduled Component Change-Out Program, preemptively replacing components before failure based upon manufacturer's recommendations and/or predictive failure analysis? (of 129 respondents)					
# YES	Percent YES	# NO	Percent NO	# No Response	Percent No Resp.
50	39%	76	59%	3	2%

Major Parts with Extraordinarily Long Lead Times

Survey respondents were asked to describe major parts or components that have an extraordinarily long lead time to procure, resulting in significantly extended bus down time. Following is a listing of the many responses:

PARTS REQUIRING EXTRAORDINARILY LONG LEAD TIME
COMMENTS FROM RESPONDENTS

Axle components	Selected brake calipers	Articulated joint parts.
Major A/C parts condensers	Selected steering & suspension parts	Electronic systems components
Exhaust after-treatment particulate traps have had a history of sporadic availability	Fuel tanks for selected buses	OEM components and parts
UK supplied fleet specific parts for obsolete fleet	Emission control equipment	Major body parts for all bus fleets
Selected Body Parts	Bus side and other body panels	Selected engine, turbo chargers
Parts for selected buses	Transmission and Engine Parts can have up to a one month lead time	Engines replacement and bus accidents
Certain transmission replacements	Exterior body panel parts	Certain transmissions and parts. Parts for 29' coaches
Engines and transmissions	Most parts for selected buses	Engines, body parts
Body parts required for major accident damage	Selected wheelchair parts.	Some suspension components (inherent to the low floor bus)
Rebuilt engines	OEM body components Windshields and windows	Coach unique body parts such as front or rear body caps
Wheelchair Lift Repairs	Differentials, wheel chair ramps, suspension components	Some axle parts.
Wiring harnesses for hybrid components,	Not an issue on major parts. It is always the small things.	Repair parts for certain buses
Body parts	Engine exhaust manifolds	Body panels and interior parts only available from the bus manufacturer lead to extended bus down time

PARTS REQUIRING EXTRAORDINARILY LONG LEAD TIME
COMMENTS FROM RESPONDENTS (Continued)

Engine turbos	Security equipment	Destination Sign Components
CNG gas regulator	Differentials	Lifts
Some body parts	Parts that are specific to a bus manufacturer	Blower motors
Wheel chair components,	CAD/AVL system parts	Destination Sign Components
Axle parts	Electronic farebox parts	Engines and transmissions
Most CNG engine components	Automated fueling	Low-water sensor
Most engine fuel injection parts	Camera system parts, auto passenger counters, etc.	Ultracapacitors
Body parts and frame parts for accident damage repairs. Also, lift parts	Radiator cores for certain buses	Engines
Being without funding for over a year has depleted stock and caused hardship on replenishment. wedge brakes, exhaust pipes	Radio parts, wheelchair lift repair parts	Inverters
Primarily powertrain components due to lead time plus installation	We have a good inventory so we don't suffer too much from down time for parts	Specialized equipment such as GPS, radio system
Windows and body parts Fuel tanks. Parts for our trolley fleet	Security equipment	CNG Components (fittings, safety lines, PRD Valves)
Exhaust manifolds for engines. Turbos for engines	Differentials	Engine and transmission rebuilds
Auxiliary Heaters	Parts that are specific to a bus manufacturer	Rear axle of artic.
Front axle-calipers, rotors.	CAD/AVL system parts	Fuel Tanks "H" Frames Transmissions and Engines Emission parts
Articulated bellows	Electronic farebox parts	Destination signs Selected parts
Articulated joints	Workhorse chassis parts	Frame structures

PARTS REQUIRING EXTRAORDINARILY LONG LEAD TIME
COMMENTS FROM RESPONDENTS (Continued)

Transmission replacement or rebuild	Turbos, and engine rebuilds	Outside major body repairs
The newest hybrid vehicles seem to have specialty components that are hard to come by resulting in excessive down time	Differentials; transmissions & parts; lighting components; some windows; seating; interior panels and some body parts	Major components such as: body and frame parts, parts needed for rebuilding and repairing sub-system components
None	We do not have an extraordinarily long lead time for any parts at this point	Engine components, brake pads and glass products (windows)
Side Windows on some vehicles Rear doors Turbos Engine Transmissions Radiators (depending)	We do not have an extraordinarily long lead time for any parts at this point	Wheel chair lifts and ramps have a lead time of six to eight weeks. This has lead to the parts department purchasing two at a time to help eliminate a bus from being down for such a long time
Engine fan motors and steering boxes and many other components; selected engines	Transmission parts	Wiring harnesses, Engine Cradles, Differentials, Suspension I-Beams
Major body parts	Steering and suspension components.	Major components such as: body and frame parts, parts needed for rebuilding and repairing sub-system components
Most body panel parts. Passenger window glazings	Rear end parts	Outside major body repairs
Transmission replacement or rebuild	Major electrical harnesses	Engine components, brake pads and glass products (windows)
Anything related to headsigns, Annunciator, Surveillance, or Hybrid systems	Body parts, specialized glazing (especially on the new next generation buses, some electronic modules and/or components	Wheel chair lifts and ramps have a lead time of six to eight weeks

OTHER RELATED PARTS & COMPONENT COMMENTS FROM SURVEY RESPONDENTS

"The newest hybrid vehicles seem to have specialty components that are hard to come by resulting in excessive down time."

"We keep a sufficient amount of parts inventory to mitigate long lead times of some replacement parts."

"As buses near retirement many vendors discontinue parts before we reach our 12-year life span of a bus, creating long lead times for parts to be manufactured again."

"Transmissions, engines, frame/structure parts, electronic modules, differential components. Differential housings routinely take over a year to bring on property, as is often the case with articulated section parts (cylinders, sensors, damping plates, accumulator), traction generator, traction motors, NiCad batteries, propulsion control systems as well..."

"As components and/or bus manufactures become obsolete, or go out of business, some items may have extensive lead times if they are available at all…With the continued change in technology and the short life of some suppliers, this has been a problem."

"The hybrid fleet has some parts that we don't stock due to high cost and no experience, however, these critical parts are in stock at the factory so this has not been a problem. We also have a fairly homogenized fleet in terms of major drive train architecture. This allows us good flexibility in moving parts among drive trains and reduces our need for redundant inventories to serve unique fleets."

"OEM or specialty manufacturers parts for any vehicle in excess of 10 years old. Specialty cooling system, air intake systems, hydraulic components that have been discontinued due to restricted or unprofitable market changes. Emission control replacement packages that require substitution or modified parts to repair…"

"Because of our remote location, we tend to carry higher inventory levels than most mainland transits. As a result, we normally do not experience lengthy down times due to no parts. Our biggest problems are obtaining parts for our odd ball fleets…"

OTHER RELATED PARTS & COMPONENT COMMENTS FROM SURVEY RESPONDENTS (Continued)

"Some rear axle and suspension components, articulating joint bus parts; including curtains, body components; mainly due to collision repairs, bus radiator and charge air cooler repair. Also, many bus parts become more difficult to procure as the bus gets past its eight year life mark."

"Long lead times will change frequently between different parts and different manufacturers. The older the bus, the more the problems. When a bus company goes out of business, the new company that buys out the defunct company usually does not support the old buses. The current recession has also caused the parts replacement stock at the vendor warehouse to be down sized. This increases lead time by a month or more."

"Our min/max stock levels account for lead times thus preventing/avoiding long lead times for material/component holds."

"A good bus maintenance program should anticipate parts needs over an extended period."

Bus Replacement and Rehabilitation Schedules

Following is a summary of survey responses to the question: *"Does your organization have a consistent bus replacement or major rehabilitation schedule? Under this schedule, at what age (in years) is a bus replaced or rehabbed?"*

Of 129 Respondents:	CONSISTENT BUS REPLACEMENT SCHEDULE?	AVERAGE SCHEDULED REPLACEMENT POINT	AVERAGE SCHEDULED REHAB POINT
PERCENT 'YES'	76%	12.5 Years	6.7 Years
PERCENT 'NO'	22%	N/A	N/A
PERCENT 'BLANK'	2%	N/A	N/A

Inactive Reserve Fleet

Following is a summary of survey responses to the question: *"Does your organization have an inactive reserve fleet? If so, how many vehicles are typically kept in inactive reserve?"*

Of 129 Respondents:	INACTIVE RESERVE FLEET?	AVERAGE # OF BUSES IN INACTIVE RESERVE
PERCENT YES	37%	16.2
PERCENT NO	62%	N/A
PERCENT BLANK	1%	N/A

FINDINGS

Overall, the transit industry has a very serious problem in attracting, retaining, and training sufficient numbers of mechanics and technicians that are able to maintain and repair today's technologically complex transit fleet and the myriad of systems and sub-systems. While some agencies are better able to meet these challenges than others, the impacts are ultimately manifested in the time period it takes to inspect, diagnose, and repair a bus that has come in for component failure or preventive maintenance. The longer this time period takes, the longer the bus is down and an appropriate spare bus needed to replace it in revenue service. This is the nexus with the spare ratio. The enormous challenges facing Bus Fleet Maintenance programs are clearly straining the spare bus fleet for many agencies as they struggle to ensure that the sufficient number and types of buses are available to protect daily revenue service.

As described in the Mechanic Requirements table, the total Net Difference between the number of mechanics and technicians **required** to support the fleets and the number **budgeted** is minus-120; 73% of the responding agencies indicating that they are not in need of additional budgeted positions and 21% of the agencies reported that they do need additional budgeted positions. The largest net budgeted need of mechanics/technician positions at a single agency is a significant shortfall of 32 slots.

At first glance, this does not appear to indicate a serious problem. However, even though a position is budgeted, it does not mean that it is filled. The essay responses to the survey question: "What, if any, challenges has your organization experienced in Attracting, Retaining, and Training qualified mechanics/technicians?" are particularly noteworthy. While some agencies indicated that they had no problems at this time, the bulk of respondents expressed numerous challenges and concerns. The most significant challenges emerging from the survey are:

Finding Experienced Mechanics: In several local labor markets, there is a limited-to-non-existent pool of mechanic/technician applicants that are qualified and experienced enough to handle the technological proficiency requirements of the transit agency's fueling/energy systems and on-board advanced technologies.

Insufficient Pay: The pay scale and/or pay progression offered is not sufficient to attract and retain qualified mechanics/technicians relative to other competing organizations and industries.

Bad Hours/Days/ Job Progression: The hours, work days, and job progression discourages otherwise qualified applicants from seeking work (or staying with the transit agency). Under labor agreements, newly entering or low seniority employees frequently have to work graveyard shift and weekends; similar work at other work places (e.g., truck repair) may offer better work schedules to the less senior employee. As well, some contracts require a job progression starting at Service/Cleaner positions before advancing on to Technician or Journeyman Mechanic. This discourages many qualified individuals from applying.

Training Issues: Many issues are faced by transit agencies who develop and support their own mechanic/maintenance training programs, including the difficulties in keeping up with the latest technology, having sufficient funding to keep the programs going at a high-quality level; and making the employees available for the hours required for training (pulling them away from their much needed shop work).

While some agencies indicated that the recent economic downturn has somewhat improved the ability to attract new mechanics, the technical demands remain as well as the ever-diminishing funds available for much critical training programs.

Toward meeting the rigorous demands of maintaining their agency's bus fleets and meeting the daily service pull-out requirements, nearly two-thirds (62%) of transit organizations surveyed operate three or more maintenance shifts.

Compounding the staffing challenges in bus maintenance departments are the numerous parts, components, and systems requiring extraordinarily long lead times to procure. While prudent inventory planning and management can anticipate the need and stock levels for many items, others must be secured when parts and components actually fail. If such a part or component is required to safely and reliably keep the bus in service, the result is increased down time and the need for spare bus coverage to maintain revenue service.

APPENDIX D

CASE STUDIES

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CASE STUDY: City of Culver City Transit, Culver City, CA

This summary was based upon a May 7, 2009 telephone interview with Paul Condran, Fleet Maintenance Manager, City of Culver City (referred to in this summary as "the City"). Data in the table below were drawn from the 2007 National Transit Database (NTD) and the City's response to the On-Line Survey conducted for the Project.

CASE STUDY AGENCY	Vehicles Available In Maximum Service (2007 NTD)	Vehicles Operated in Maximum Service (2007 NTD)	Fleet-Wide Spare Ratio (Calculated)	Number of Fuel Systems (Survey)	Number of Advanced Technologies (Survey)	Number of Service Types (Survey)	Method of Service Delivery (Survey)
City of Culver City Transit (Culver City, CA) Service Area Population 298,478	46	33	39%	1 (CNG)	12	1	Directly Operated

1. **How has the diversity of your fleet mix impacted your agency and your ability to operate within a 20% spare ratio?**

The City currently has 52 buses, representing a mixed fleet of 30-foot, 40-foot and 40-foot BRT buses, this is two units beyond the current limitation-threshold for application of a 20% spare ratio. The City has a new bus purchase scheduled for the FY 09/10 fiscal year to replace 20 buses. This will be a mix of 40-foot BRT and 40-foot standard buses.

In 2012, the City is planning on acquiring six new 60-foot articulated buses (four to operate and two spares); while this may or may not increase the total fleet some of these buses will be considered as replacement buses. This will change the City fleet significantly; as it will then have 30-foot, 40-foot standard, 40-foot BRT, and 60-foot articulated buses. This widely diverse fleet mix will be uncharted waters for our small fleet, with many challenges expected.

2. **How has the introduction of new fuel/energy system technologies, along with the traditional propulsion systems, impacted your organization and your ability to operate within a 20% spare ratio?**

The City's bus fleet is exclusively powered by Compressed Natural Gas (CNG). The City was mandated to operate alternative fuel technology many years ago because it is within the South Coast Air Quality Management District (AQMD) containment area. Compressed Natural Gas (CNG) is a safe and extremely clean fuel and operates well while offering outstanding environmental benefits, however. This advanced fuel technology creates several challenges. There is a need to think differently regarding advanced technology fuel systems such as CNG. In the City's experience, these systems are more difficult to operate and repair (then diesel), have a higher cost of operation because of parts, and experience slightly more downtime because of longer inspection criteria.

The City has been operating CNG buses for 11 years. CNG parts are more expensive and take longer lead times to obtain. There is also a shortage of qualified, experienced, journeymen technicians that are qualified to work on CNG systems; there is a need to go beyond basic diagnostics to advanced diagnostics. As experienced mechanics leave, and new mechanic/technicians enter the workforce, they require more training. The parts and labor challenges extend the downtime of vehicles that would otherwise be in revenue service, resulting in the need for more spare buses and affecting the spare ratio.

Buses not only wait longer for parts, but diagnosing electronic problems can sometimes take many hours. For a proper diagnosis, the mechanic must hook up a laptop (before other conventional tools), and read/identify the codes, understand what is on the display, identify schematics and distinguish the part(s) that is required to be replaced. Electronic sensors need to be installed very carefully and sometimes reprogrammed. It takes time to do it properly.

CNG's special fuel distribution systems and high pressure make it inherently different from traditional diesel (e.g., special tubing, fittings, and fuel regulation to drop pressure). Mechanic/technicians must be able to diagnose problems in a very systematic, prudent manner. Incorrect repairs can also be costly as the high pressure can cause expensive damage. It takes more time (than on advanced diesel systems) to diagnose CNG systems properly.

There are hundreds of special parts, many of which are uncommon and expensive. Because it is a small property, the City can't afford to maintain a full inventory of all parts only to sit idle on the shelf until they may be needed. This often means waiting for specialized part(s) once it is ordered.

All of these issues impact spare bus needs and the spare ratio: the downtime, repairs, parts waiting, and fuel system diagnosis. Available spare buses are at a premium; meeting pullout is critical. With a larger number of spare buses available, downtime would not be as critical in making vehicles available for service.

3. How has the implementation of advanced on-board technology systems and equipment affected your agency and your ability to operate within a 20% spare ratio?

Longer diagnostic times require specialized experience. The City has found that in many cases, labor has not yet caught up with advances in technology. There is a shortage of technically-prepared and experienced mechanic technicians to replace the older employees as they leave the organization; this is an industry-wide problem. Young people do not want to become mechanics anymore, even though the transit industry will continue to lead the way in advancements in technology.

Many new mechanics enter the field as specialists, and do not possess the well-rounded aptitude necessary for transit fleets. For example, they may be good at diagnosing engine or advanced technology problems, but are not competent on brakes, transmissions, and/or high pressure gas fuel systems—and vice versa. Very few have the experience where, with some limited additional technical training, they could diagnose and repair all required systems on all buses, including the advanced technology systems. The City has found that this impacts down time which also impacts spare bus needs and ratios.

To mitigate this, the City created self-managed work teams; aligning people with complementary technical skills and co-mingling them to work on same work unit as "self-managed work teams". This approach has worked well. Over time each person learns necessary technical skills from each other and they complement those skills.

Other challenges include the limited availability of parts for the advanced technology systems (e.g., AVL parts). These parts and components all take a long time to obtain and the systems have long diagnostic times, also affecting downtime and spare bus requirements.

4. **How has the scope and nature of the services you offer to the public, and the interchangeability limitations between sub-fleets, impacted your ability to meet daily pull-out requirements while operating within a 20% fleet-wide spare ratio?**

To accommodate its anticipated new BRT service, the City will have fewer vehicles with which to service local routes. Fleet spares are limited and at capacity. As service and amenities for the public are improved and expanded, this sets up high expectations which will need to be met consistently, every day. This creates new challenges in the area of fleet interchangeability as we are operating a sub-fleet.

For example, the City tested wireless internet (or "Wi-Fi") on several buses and they were deployed on the City's busiest route serving UCLA. Wi-Fi was provided on that line free of charge as a pilot program. It was very well received and, since this was a test project, non-Wi-Fi-equipped buses were also assigned on that route. When customers realized they were on a non-equipped Wi-Fi bus, the City would receive customer complaints.

Another example is on the City's Bus Rapid Transit (BRT) service. The BRT route will provide higher frequency and greatly reduced travel times as compared to local service. Customers will come to rely upon this higher level of service to get to work, school, appointments, etc. The BRT service requires specially designed buses with unique branding, new interior designs, amenities, and a special configuration to permit rapid boarding and alighting. If a BRT bus is unavailable for service and there are not sufficient numbers of appropriately configured spare BRT buses, service level may have to be reduced, impacting people getting to work.

Once the service is implemented, there is pressure for the specialized vehicles to remain in service to meet public expectations. BRT customers usually become disoriented if a bus that is not "BRT-branded" goes by—and often won't board that substitute bus. If the City has to use a standard local bus in BRT service, it may place placards on the exterior to let the public know they are "BRT buses" for that trip. For some of the reasons that BRT services are successful (e.g., the unique, easily identifiable branding and color scheme), the placards may become cumbersome and ineffective. This remains to be seen.

Conversely, a 40-foot BRT bus can't readily be put into regular local services given its unique branding, paint, and interior, etc. without customer confusion. As well, 30-foot buses can't operate on all routes due to their limited capacity and (for some) single-door.

The City also operates several tripper buses each weekday to mitigate peak operating impacts, deploying them to supplement the regular fleet, "catch-up" the schedule, and provide supplemental capacity on routes near schools to accommodate student customers when school lets out. The tripper buses are typically 40-foot standard coaches. The 30-foot buses in the fleet can't replace the 40-foot workhorse because there is not enough passenger-carrying capacity. Buses used in tripper service are not available as spares.

The City will soon be repainting six to eight of the regular 40-footers and converting them for BRT use to meet demand for capacity on the BRT line. This will further exacerbate the (lack of) interchangeability issue and its impact on maintaining a 20% spare ratio. In addition, with a new light rail line opening soon (Expo Light Rail from Downtown Los Angeles to Downtown Culver City), there will be the need for additional feeder service to the station and transit hubs. The City is not yet certain what the passenger demand for that feeder service will be and whether they will need 40-foot or 30-foot buses to serve the station.

5. **How have workforce constraints and the support of your advanced fuel systems and other on-board technologies challenged your maintenance programs in maintaining, servicing, and fueling your fleet?**

This has already been touched on in previous questions. One of the other constraints that the City has faced involves the cross-training within the previously mentioned self-managed work teams.

There is a thin line between rebuilding (by a journeyman) and replacement (by an assistant mechanic). The assistant needs to work with a journeyman to learn how to rebuild components. This has created union assertions that the assistant is working "out of class," resulting in the potential for claims for additional compensation for the assistant. The City has been able to work through this and other similar issues with the Union through compromise, good communication, and a commitment to work together. Union issues are not currently a major factor impacting spare bus needs, although they had been in the past.

6. **Please describe any special characteristics of your operating environment that place special demands on your peak and spare bus fleets (e.g., temperature extremes, snow and ice, urban congestion, topography, etc.)**

City transit services are provided in Los Angeles County where heavy passenger load conditions are encountered while operating in extreme traffic congestion. In addition, during Southern California summers, daytime temperatures can get very hot. Individually, each of these conditions can be very challenging; when they occur in conjunction it can be even more taxing.

The City frequently needs to change-out buses in summer when the air conditioning systems are not able to keep up with the ambient air temperatures. Advanced technology heating, ventilation, air conditioning (HVAC) systems, similar to those in homes and offices, have limitations with their programmable thermostats in a transit environment. For example, if the thermostat is set at 70 degrees and the windows and doors are constantly opening and closing with a full load of passengers, then the system runs constantly; and to protect itself from an

over-charge condition, it goes into a protection mode and modifies the systems temperature. When that condition occurs on several vehicles during peak periods, there are not enough spare buses to replace them. This situation is coupled with the assignment of peak-hour tripper buses, drawn from the same spare bus pool, to mitigate traffic impacts.

Other challenging operating conditions include two routes with very steep hills. When buses on those routes have a standing load, they crawl up the hill at very low speeds. The City doesn't have the luxury of reprogramming the horsepower points to obtain more torque to power up the hill, since this is only needed on certain buses (for operation on the two routes) and wouldn't be feasible on the remainder of the fleet.

Graffiti and vandalism are a major problem facing the City fleet. The City has a zero-tolerance policy. A bus doesn't go into revenue service if it has been marred or defaced. They have installed replaceable, easily removable graffiti shields. However, when there are gouges or deep scratches, vandalism repair can take more time.

All of the above items have a significant impact on spare bus needs, and necessitate higher spare ratios if service quality is to be maintained.

7. What is the average annual vehicle mileage per bus for each sub-fleet you operate (this will be validating data provided in the survey)?

30-foot bus:	20,000 average miles per bus
40-foot bus:	38,150 average miles per bus

8. What is the average number of revenue hours per day per bus by sub-fleet?

	Revenue Hours (incl. deadhead)	Est. Hours Avail for Service
40-foot BRT buses	11 hrs/day	13 hours
30-foot buses	11 hrs/day	13 hours
40-foot standard (Local) buses	14 hrs/day	8 hours

For the 40-foot BRT buses and 30-foot buses, there are approximately five hours available for preventive maintenance (PM) inspections, servicing, and repairs between peak periods. The 40-foot standard (local) buses are out on the street all day. For those vehicles, daily fueling, washing, cleaning, graffiti removal, and safety-related repairs must occur between evening pull-in and the next day's pull-out. For PM's and major repairs, they must pull the 40-foot standard (local) buses out of service and replace them with a spare during the service day. This critically impacts the spare ratio.

9. **Has your agency implemented specific policies, procedures, and/or practices aimed toward more efficiently managing your fleet and keeping spare bus requirements to a minimum?**

In addition to the "self-managed work teams" previously noted, there are two other practices worth mentioning.

Maintenance Standards: The City has very extensive Maintenance Standards defining expectations on every maintenance parameter for each bus type; standards include the expected time-to-repair; vehicle down time; and parts required (this enables certain parts to be pulled beforehand to reduce down time). The standards clearly define the expectations of maintenance staff. Everyone knows what expected of them and the tools available to meet (or exceed) those expectations. The City has found that the standards help mitigate bus availability challenges. The standards help manage available equipment since there is a clear expectation of downtime for each repair or PM.

Preventive Maintenance: The City has a strong Preventive Maintenance (PM) program which they believe is a key to controlling costs. One of the challenges of supporting the PM program is the lack of sufficiently available hoists or repair bays. If the maintenance staff discovers a needed repair and it is not a safety issue, they will usually have to put the bus back into service and then reschedule it for the repair. It is not the most efficient way to go, but often they don't have available spare vehicles to keep the bus out of service in order to obtain the parts and complete the needed repair (if it is safety-related, it is repaired immediately before the bus is returned to service). The availability of more repair bays and more spare buses would greatly improve efficiency and out of service percentages. It would reduce down time since that vehicle is already in and on the hoist, the part is already exposed and accessible for repair, and could be repaired then and there.

Conclusion

The City Maintenance Department has a policy that places great emphasis on Customer Service and measures satisfaction annually through customer surveys. Its goal is to achieve a 95% satisfaction rating among transit customers. To accomplish this requires the delivery of safe, reliable, clean, and attractive transit services every day. At any given time, 10-15% of the City's bus fleet is out of service for maintenance needs: PM's repairs, body work, repairs, inspections, etc. Daily pull mandates are sometimes difficult to maintain as the need for buses remains great. Having a sufficient spare ratio to assist with the challenges described above is a critical element to maintaining the high customer satisfaction that the City strives for while protecting the public investment in its transit fleet.

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CASE STUDY: Niagara Frontier Transportation Authority (NFTA), Buffalo, NY

This summary was based upon an April 30, 2009 telephone interview with Thomas Marsteller, Maintenance Superintendent, NFTA and Gene Fezer, Maintenance Coordinator, NFTA. Data in the table below were drawn from the 2007 National Transit Database (NTD) and the NFTA's response to the On-Line Survey conducted for the Project.

CASE STUDY AGENCY	Vehicles Available In Maximum Service (2007 NTD)	Vehicles Operated in Maximum Service (2007 NTD)	Fleet-Wide Spare Ratio (Calculated)	Number of Fuel Systems (Survey)	Number of Advanced Technologies (Survey)	Number of Service Types (Survey)	Method of Service Delivery (Survey)
Niagara Frontier Transportation Authority (Buffalo, NY) Service Area Population 1,182,165	334	286	17%	2 (Diesel and Hybrid-Diesel)	12	5	Directly Operated

1. **How has the diversity of your fleet mix impacted your agency and your ability to operate within a 20% spare ratio?**

Maintaining a diverse fleet is a challenge. It takes both the right knowledge and materials. NFTA's diverse fleet makes it harder to keep needed part inventories for all vehicles; there are sometimes multiple generations of the same engine (different fuel and emissions packages) that require different sub-inventories of certain parts. Two buses sitting side-by-side may appear to be the same, yet may have very different maintenance needs and requirements.

In the old days, the NFTA fleet consisted of GMC "Silver Sides." All the buses in the fleet were the same. Virtually all parts were interchangeable between buses, even different models. There were very few electronic components—e.g., the ballast assembly to run dome lights. Even the speedometer operated with a cable. The only special training needed was focused mainly on air conditioning refrigerant recovery and recycling (608/609 certification).

The GMC buses at NFTA were pretty simple to diagnose. The coaches started getting more complex in the 1970's with the addition of climate control systems, and became increasingly complex with the introduction of radio systems. In the 1980's, more technology was introduced with wheelchair lifts; maintenance on the lifts was critical to keeping them operable for customers with disabilities. In the 1990's, new emissions systems were introduced, as the diesel engine moved from "dirty" 2-cycle to 4 cycle technology; catalytic converters and particulate traps were added. The technology continued to evolve with special exhaust treatment/fluid systems.

Now the NFTA bus fleet is much more diverse. To meet the technological and fleet diversity challenges, NFTA had to improve their processes and systems. Mileage and hours were increasing, meaning less bus downtime was available for maintenance work. They needed to move personnel between shifts and be more efficient in organizing work. They also implemented a management information system to track work orders.

2. How has the introduction of new fuel/energy system technologies, along with the traditional propulsion systems, impacted your organization and your ability to operate within a 20% spare ratio?

NFTA has 43 hybrid electric-diesel buses. The first group they purchased was in 2006 with a second group acquired in 2007. They experienced many challenges and growing pains with this large commitment to hybrid technology. The Energy Storage System was a problem area as were the hybrid drive management, wiring, and engine accessories. NFTA didn't get the required service and support as expected. They had to dedicate quite a bit of time to working through the challenges of the initial implementation. Some maintenance challenges continued even after this initial break-in. New issues continue to arise. Recently, 5 out of 43 hybrid buses were down at the same time due to a failed Dual-Power Inverters Module (DPIM).

Overall, the 2006-built hybrids have averaged slightly above the total fleet average of mean time between failures. With considerable improvements made in the wiring harness and drive train, the 2007-built hybrids have been above the total fleet average of mean time between failures.

There are new challenges on the horizon in getting ready for the Diesel Emission Reduction Act requirements. This will bring about new technology, necessitating the training of mechanic/technicians on new equipment. Coach operators must also be trained in exhaust

management to reduce excessive idle time. This will present challenges during the Buffalo winters where cold weather may prevent the bus from starting again if it is shut off.

The new upcoming emission standards will require different grades of exhaust management. They also require three different sets of components. There is limited knowledge of how it will operate in the real world. It will likely impact maintenance requirements to a significant degree.

All of this means more maintenance time required and increasing demands on available spare buses.

3. How has the implementation of advanced on-board technology systems and equipment affected your agency and your ability to operate within a 20% spare ratio?

At NFTA, there is a high demand locally for new advanced technology, mainly driven by customer service needs. These systems include Global Positioning/Automatic Vehicle Location Systems, Bus Stop Enunciation Systems, and Automatic Passenger Counting. NFTA has also implemented Multiplex systems—designed to minimize amount of wiring on the buses. With Multiplex, a single hard-wired line can handle the multitude of data transmission needs from front to rear of the bus. Another advanced technology system implemented in the NFTA fleet is Automatic Traction Control on the hybrids to help operators maintain control of the bus in icy conditions.

Of all the on-board technology systems, the most maintenance-intensive is the fare collection system. Fare boxes are a weak link. If the farebox experiences a failure, they try to change out the bus as soon as possible. Fareboxes are very susceptible to vandalism as various customers frequently try to deliberately jam the mechanisms.

The tremendous amount of road salt used in Buffalo area snow and ice removal has a major impact on all bus electrical and advanced technology electronic components. Salt dust circulates throughout the bus' air handling system and corrodes wiring and connections everywhere on the vehicle. The lighter-weight alloys used in today's advanced bus are particularly susceptible to corrosion. In this environment, there is no such thing as a waterproof, weather-proof connection.

According to NFTA, there has been significant technology introduced since 2000. Most of the technology is very experimental. Vendors are putting products out rapidly. NFTA and other transit agencies are at the forefront of trying new technology that is often unproven under the rigors of daily service. NFTA and other transit fleets have become a proving ground, implementing rapidly changing technologies on a regular basis. As first-line users, there are many challenges. While in-service testing of the new technologies is a good thing, it is not always helpful in putting needed vehicles in service and keeping them out there.

Even with less innovative components, NFTA has had challenges. A set of transmissions was failing after 25,000 to 30,000 miles (they normally have a 250,000 mile life cycle). 117 buses had those transmissions and were failing on the street. It took five years to get them to an acceptable state of reliability (gradually improving mileage between failures from 25,000 to a norm of 250,000), working with the manufacturer over a long period of time. During that period, reliability suffered—and NFTA wasn't meeting its customer service and reliability expectations

All of the above issues have significantly impacted NFTA's maintenance needs and spare bus requirements.

4. How has the scope and nature of the services you offer to the public, and the interchangeability limitations between subfleets, impacted your ability to meet daily pull-out requirements while operating within a 20% fleet-wide spare ratio?

NFTA is constantly evaluating its service and ridership to determine appropriate bus size needs and assignments. In Niagara Falls service, for example, there is a need for smaller buses. The 30-foot buses at NFTA were purchased to meet specific demands—confined areas, narrow streets, and on routes where ridership does not require a 40-foot bus. On a given day, when there are not enough 30-foot coaches for service, they use a 40-foot low-floor bus with a smaller turning radius. They then have to prioritize repairs of the 30-foot buses to get them out as quickly as possible.

The 2004 buses in the 30-foot subfleet are as reliable as the 40-foot coaches; they are designed for the same duty cycle and have proven technology. The less-than-30-foot buses, however, are a maintenance challenge. For these smaller buses, NFTA tries to keep the average fleet age at 5 to 7 years. When the less-than-30-foot buses exceed five to seven years of age they require more than just preventive maintenance including body and chassis repairs. The less-than-30-foot vehicles have many engine and transmission challenges that can affect their reliability. New buses are not always the answer. Their new 2008 "cutting edge" less-than 30-foot buses have significant power train issues related to their new emissions system. This issue can impact the service in which the small, less-than-30-foot buses are required.

NFTA needs 40-foot buses on many routes and can't readily substitute smaller vehicles. If the only spare bus available is a 30-foot bus, they will place it into service even if it has insufficient passenger carrying capacity for the ridership demands of that route. They are unable to "double-head" smaller buses given added cost and service requirements.

NFTA runs peak-hour commuter service; these are long-distance runs as long as 40 miles one-way. If, due to spare bus limitations, they have to place a small bus on these routes, it results in many standees and customer complaints.

NFTA operates buses out of three garages that are geographically spread out. There are spare ratio challenges at each facility. They often have to transfer buses between facilities to meet weekend service needs (and pay the added cost to transfer equipment) then transfer the buses back for weekday use. This is expensive and inefficient.

Interchangeability problems are sporadic for NFTA. They can be climate-driven such as during severe winter weather when ridership spikes (because people don't want to drive in heavy snow). NFTA has also seen ridership increases with the increased cost of gasoline. When these spikes occur, the interchangeability (or lack thereof) of the spare bus fleet can be problematic. On normal days, however, NFTA generally has enough appropriately-sized spare buses in the subfleets to handle the ridership demands and operational constraints.

5. How have workforce constraints and the support of your advanced fuel systems and other on-board technologies challenged your maintenance programs in maintaining, servicing, and fueling your fleet?

Training is a challenge for NFTA, particularly in getting long-term mechanics up to speed on highly technical systems. For many long-time mechanics and technicians, developing the ability to learn the skills needed for the advanced technology systems is not an easy transition. At NFTA, new mechanic/technicians must take a skills test to measure their competency. Long-time mechanic /technicians (hired before a December of 1996-bus contractual issue) are grand fathered and are not required to take the skills test. If an employee was "qualified" as a senior-level mechanic 20 years ago, he/she may need to be trained to bring them up to speed on the new technology. Some of these individuals have never used a laptop computer—a critical tool for running the diagnostic tests on the advanced technology systems.

At NFTA, the maintenance employees are a Union-represented group. Many memoranda of understanding (MOU's) date back a long time; some MOU's are over 30 years old. More cost-effective changes in practice are often difficult to implement because of contractual issues. The NFTA maintenance workforce is very diverse in terms of the age and tenure of mechanic/technicians; it contains both senior people and employees that are relatively new. Newer workers are more inclined to learn new technologies. NFTA has found it harder to attract younger workers to become bus mechanics (as opposed to becoming car mechanics). As a rule, some newer employees are not comfortable on the "wrench turning" end, but are more comfortable using laptops and computer-based diagnostic systems. The older, longer tenured workers generally excel at "wrench turning," but tend to avoid electronic diagnosis and wiring repair.

The NFTA can't offer more experienced individuals starting pay commensurate with their experience since there is a 4-year progression to get to the top pay step. A new employee with significant experience would have to start at the first step in the progression which may be a

significant pay cut for him/her. Also, as a new employee to the organization, even with significant experience elsewhere, they would have the lowest seniority and get the least attractive work shifts: relief shifts, weekends, holidays, etc. The pay and work assignment issue impacts NFTA's ability to attract experienced mechanic/technicians from the outside.

In the maintenance of automobiles and school buses, mechanics tend to be very specialized. At NFTA, bus diesel mechanics need to do more than running repairs. They need mechanics that are capable of working on the whole bus and all of its systems. For that, you need diverse and talented mechanics (with many niches)—one that can work on air conditioning, brakes, steering, wheelchair lifts, electronic systems, and power train elements.

Transit vehicles are very specialized, customized vehicles. Many parts have a significant lead-time to procure if they are even available as the vehicles age. At NFTA, most repairs are done in–house. Many agencies purchase new or rehabbed components and/or send out the component for repair. Not at NFTA. It is a historically old company where even starter motors are rebuilt in their facility. There are a number of inefficient and non-cost-effective examples such as this, which require collective bargaining to change.

6. Please describe any special characteristics of your operating environment that place special demands on your peak and spare bus fleets (e.g., temperature extremes, snow and ice, urban congestion, topography, etc.)

The Buffalo-Niagara Falls area in the Great Lakes region gets a tremendous amount of lake-effect snow throughout the winter. While other cities have colder winters, like Montreal or Minneapolis, Buffalo differs in its amount of winter precipitation, rapidly changing temperatures and the amounts of road salt used. During the winter in Buffalo, after a snowfall, the goal is to keep roads wet with no ice—this requires the spreading of huge amounts of road salt. As mentioned previously, the new lighter-weight metal alloys don't respond well to the salt, as the resulting chemical reactions causes corrosion of parts, wiring, and other components. The salt also gets into the vehicle, on seats and floors, and is very time-consuming to keep clean.

Cold weather can also impact mechanical systems. In 1995, 67 new buses, in their first winter of operation, all went down on the same day. The kneeling valve failed when temperature dropped from 40 degrees to minus-20 in five hours. The system had a design flaw, which was corrected by the NFTA.

In Buffalo, there is much urban congestion, stop-and-go driving, and very rough roads due to the severe freezing and thawing conditions. Buses are often driven through pot-holed streets causing much tire and suspension damage. With the slippery roads and on-street parking, there is lots of body work that needs to be done by the NFTA maintenance department in response to accidents.

7. What is the average annual vehicle mileage per bus for each subfleet you operate?

40-foot Bus:	30,880 average vehicle miles per bus*
30-foot Bus:	43,371 average vehicle miles per bus**
Less-than-30-foot Bus:	55,542 average vehicle miles per bus

Note: *The 40-buses at NFTA average 12 miles per hour.
**The 30-foot buses operate at higher speeds in less congested areas.

8. What is the average number of revenue hours per day per bus by subfleet?

NFTA's 40-foot and 30-foot buses are operated 8.53 revenue hours per day (not including deadhead). Their less-than-30-foot buses are operated 6.77 hours per day (not including significant deadhead hours and miles)—these are typically run in ADA and non-ADA service.

The earliest buses pull out at 4:10 a.m., with the last buses returning to the base at 2:00 a.m. Approximately 90% of the fleet is back in the garage between 11:30 p.m. and midnight, and 90% of the buses are back out again between 7:00 a.m. and 8:00 a.m.

On split runs, there is a two to four hour mid-day gap when the buses are back at their respective garages. On average, a vehicle inspection takes two to 2.5 hours. NFTA would be rushed to do repairs in between splits. Unless it is a very minor repair, they schedule it for another time. For safety related defects, the bus is parked until the repair can be made. Most major repairs and running repairs are performed on second and third shifts. During the day (first shift), they do mostly Preventive Maintenance work (PM's) using spare buses, including PM's on brakes, air conditioning, wheelchair lifts, engines, and transmissions.

9. Has your agency implemented specific policies, procedures, and/or practices aimed toward more efficiently managing your fleet and keeping spare bus requirements to a minimum?

NFTA has begun special dispatcher and operator training. The objective is for dispatchers and operators to become more familiar with the many systems and subsystems on buses in each of the diverse subfleets. The goal is to achieve better operator understanding of indicator lights and gauges to enable better in-service assessments of a vehicle's ability to continue in service (or not). It is also intended to minimize service calls and down time.

NFTA also conducts proactive mechanic training with a focus on its maintenance standards. No one size type fits all, so documents are being developed for the PM inspection procedures for each type and style of vehicle with appropriate modifications to the inspection routine to account for different makes, models, engine types, etc.

NFTA is striving to provide significant information and documentation to each member of the maintenance staff. The Maintenance Department feels that creating individual sets of documentation for each mechanic/technician will diminish the need to take the time-sharing books (it also minimizes pages being torn out of manuals). This also addresses the numerous deficiencies in documentation and reference materials NFTA has received from bus manufacturers, including manuals and wiring diagrams.

NFTA has become more proactive with oil analysis and the monitoring of fuel consumption, contamination, and tire wear, etc. They do more forecasting and trend analysis. With this increased diligence, they can better anticipate failures to ensure that components and systems are not getting to a critical stage where they may fail in service. This has enabled the preemptive change-out of components and parts before failure, which has customer service benefits (e.g., avoiding a service interruption) and cost savings (e.g. doing an in-frame overhaul).

Conclusion

NFTA has expressed that just because they operate within a 20% spare ratio doesn't mean it's not without daily sacrifices, inefficiencies, and quality compromises. Those tradeoffs, while not safety related, do impact customer comfort, cleanliness, service reliability—and overall customer satisfaction. While they make do within the 20% ratio, they are not satisfied with the impacts. In daily calls, sometimes when they are focusing on steering and braking (safety), they have to tradeoff not working on air conditioning/climate control systems that are not working or not running at full effectiveness. NFTA does not have a sufficient number of spare vehicles to address buses that are out of service due to major mechanical failure and accident repair in addition to covering for those vehicles that are out of service for running repair or PM's.

While NFTA may meet their daily pullout requirement, they may not always be able to provide high-quality service. While 293 buses (not including demand response buses) are currently pulled out every day, not all are able to stay in service the entire day. When buses breakdown and require a service call, NFTA feels they are not adequately meeting customer expectations. Prior defects may come back. There is not an adequate spare ratio to fully troubleshoot and make repairs to bring buses to a "like new" condition. They may have to do a quick repair, but is not necessarily a preferred quality repair on the street.

With a limited spare fleet, NFTA can't be as proactive as they want and need to be. They are too often in a reactive mode. For example, if NFTA had more spare vehicles, during an inspection they could have all repairs completed while the bus is in the shop—and then return it to service. Currently they have to prioritize, often sending a bus back out into service with non-safety related defects, which are then scheduled back in for the repair. This is highly inefficient and costly.

NFTA believes that a higher spare ratio would help. Under the current spare bus levels, they are challenged daily just to make pullout. It is very inefficient. Frequently, buses are unavailable as a result of repair times for new technology/subsystems, parts availability and buses out of service for major repair and accident damage. Ultimately, these compromises impact customer satisfaction—and the ability to provide a clean, comfortable bus. They improvise a lot, though never compromising safety.

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CASE STUDY: City of Phoenix, AZ, Public Transit Department

This summary was based upon a May 8, 2009 telephone interview with Al Villaverde and Reed Caldwell, Deputy Public Transit Directors with the City of Phoenix Public Transit Department (referred to in this summary as "the City." Data in the table below were drawn from the 2007 National Transit Database (NTD) and the City's response to the on-line survey conducted for the Project.

CASE STUDY AGENCY	Vehicles Available In Maximum Service (2007 NTD)	Vehicles Operated in Maximum Service (2007 NTD)	Fleet-Wide Spare Ratio (Calculated)	Number of Fuel Systems (Survey)	Number of Advanced Technologies (Survey)	Number of Service Types (Survey)	Method of Service Delivery (Survey)
City of Phoenix Public Transit Department (Phoenix, AZ) Service Area Population 1,560,380	506	413	23%	3 (Gasoline, Diesel and LNG)	9	7	Contracted

1. How has the diversity of your fleet mix impacted your agency and your ability to operate within a 20% spare ratio?

The City and its contractors operate five different bus-size subfleets: Less than 30-foot (gasoline); 30-foot (diesel); 40-foot (liquefied natural gas (LNG) and diesel); 45' "Compo" (LNG); and 60-foot articulated (diesel). A fleet of this high level of diversity can present everyday challenges given the unique attributes of the buses in each subfleet.

For example, the "Compo" bus is a 45-foot composite material bus, made in a mold, similar to building a racing boat hull. It uses a patented fiberglass-type material with a specially made frame and axle. It is exclusively used in the City's Bus Rapid Transit (BRT) services. The Compo bus requires the mold to make major body repairs. Significant body work is very time consuming and results in lengthy bus downtime. While minor body repairs are relatively easy, the City and its contractors are not tooled up for major body work. This major body work requires the mold used to fabricate the front portion of the bus in order to make replacement panels. The manufacturer must come to the City facilities to accomplish the work.

2. How has the introduction of new fuel/energy system technologies, along with the traditional propulsion systems, impacted your organization and your ability to operate within a 20% spare ratio?

The City runs buses powered by diesel (with particulate traps), LNG, and gasoline. Their diesel buses are equipped with particulate traps and burn ultra low-sulfur fuel. All buses with particulate traps require additional maintenance; however, there are 20 buses in particular that were among the first engines in the nation developed for use with particulate traps. While the subsequent engine generations were better designed and much improved, the initial buses with traps require a higher level of maintenance.

The City has found this to be a common pattern. New technology comes out with its initial "bugs," then subsequent models are improved and refined. Meanwhile, those agencies whose buses have the initial technology still have to live with operating the earlier, higher-maintenance (sometimes less reliable) "pioneer" models. There are other examples.

The City's LNG-fueled fleet includes buses with three different generations of fuel tanks, each providing a different range the bus can operate on a full tank of fuel:

- Generation 1—100 mile range
- Generation 2—175 mile range
- Generation 3—200 mile range

Buses of Generations 2 and 3 are fairly interchangeable regarding vehicle assignment and can be placed on longer routes, however, Generation 1 vehicles must be assigned to shorter routes or they will run out of fuel before the end of their service day. The Generation 1 fuel tanks were not fully debugged. In the subsequent generations, tanks were better designed along with their larger capacity.

The City's experience is that LNG is a "whole different planet" than diesel. LNG buses have different maintenance needs, unique parts, and special facility requirements that must comply with fire codes. LNG is very specialized, making it quite difficult to find capable contractors with necessary experience to operate and maintain the LNG fleet, fueling stations, and maintenance facility modifications; they have three private operating contractors.

When the City introduced LNG buses in 1998, it was very challenging being among the first agencies to invest in this relatively new bus fuel technology. The availability of parts was very problematic. When on this "bleeding edge," a 20% spare ratio didn't work. While better today than 9 years ago, it is still difficult to operate with only 20% spare ratio. The LNG engines and fueling stations require more mechanics and more spare parts or the transit service needs cannot be properly met. LNG has a higher level of maintenance required. LNG engines run hotter in the engine compartment. With this fuel technology, there can't be <u>any</u> oil leaks due to the fire hazard. As well, the engine heat coupled with the ambient desert heat prematurely wears out rubber parts (hoses, belts, etc.).

LNG bus fuel tanks must be evacuated (all fuel removed) and reconditioned every two to three years (not required for diesel). The maintenance department can do two per night and require separate bays for this procedure. It is an additional maintenance requirement that consumes mechanic time and repair/inspection bay capacity. The LNG fueling station infrastructure also requires significant preventive maintenance (PM) of gaskets, filters, and regulators.

Anecdotally, The City has found that with the introduction of ultra low sulfur diesel fuel with particulate traps, there is not much of a difference in maintenance time/downtime when compared to LNG. The City has been dealing with LNG for nearly 10 years. There were tough times in the beginning finding qualified LNG mechanics and providing lots of special training. It is now much more routine.

3. How has the implementation of advanced on-board technology systems and equipment affected your agency and your ability to operate within a 20% spare ratio?

The City fleet has numerous advanced technologies on-board their vehicles. They have found that the more of these systems that are present on the vehicle, the more complicated the maintenance. Each individual technology system requires significant preventive maintenance time and specialized expertise.

For example, the fleet's vehicle management system, which includes automated vehicle location (AVL) and its radio system (combined voice and data), requires very high maintenance efforts. The City's contractors must hire specialized technicians to maintain these systems.

These and other advanced technologies have caused increased downtime for vehicles. The City often has to put vehicles into service with systems that are not operating properly--within reason. The City never compromises safety. Safety-related defects are addressed immediately and buses are parked or removed from service as necessary. However, if a bus has a malfunction or defect in a non-safety related system (such as electronic head sign, AVL, or fare collection apparatus, etc.), that vehicle may need to be placed into (or continue in) service to meet the daily requirement if sufficient spare buses are not available.

If a fare collection unit malfunctions while the bus is in service, the City's contractor tries to send a technician out. In the interim, the consequence is that no revenue is collected until the unit is repaired. The City is sometimes faced with a choice as to which option is least expensive—changing out the bus or foregoing the fare collection for a period of time that day.

Each high tech item individually may not have an impact on spare ratio needs, however, looking at all of the individual systems and sub-systems collectively, there is clearly an effect on spare bus requirements and the challenge of operating within a 20% spare bus ratio.

4. How has the scope and nature of the services you offer to the public, and the interchangeability limitations between subfleets, impacted your ability to meet daily pull-out requirements while operating within a 20% fleet-wide spare ratio?

If necessary, the City can use 40-foot and 60-foot buses interchangeably (they have a similar turning radius), though they typically try to put 60-foot buses on routes with large passenger loads. If a 60-foot bus goes down, they will sometime have to put in a 40-foot spare; the lower capacity can create crowded conditions for customers.

Unlike the 40-foot and 60-foot buses, the 45-foot "Compo" bus has a larger turning radius and is restricted only to operation on the BRT routes. The BRT buses are branded differently and have special interior and exterior features. The City sometimes has to run standard 40-foot or 60-foot buses (without special branding and amenities) in BRT service when a spare compo bus is not available; while possible, this situation is not ideal.

The City also runs two different sets of uniquely-branded 30-foot buses: one set operates on a downtown shuttle route and the other on a route in suburban cities. Each set of buses is especially tailored and branded for that particular application. These specialty buses are not interchangeable for operation on any other routes. The small number of vehicles in this subfleet, and the lack of interchangeability, present operational and maintenance challenges.

These challenges require a much larger subfleet spare ratio than the overall fleet in order to meet the unique service demands of each route.

In addition to the downtown circulator route, the City operates neighborhood circulators using less-than-30-foot gasoline powered "cutaway" buses. Because of a local decision not to implement as many neighborhood routes as previously planned (due to funding constraints), a recent small bus purchase contained a greater number of vehicles than presently needed for service. The original purchase reflected a 20% spare ratio. The spare ratio now exceeds 20% as a result of the reduced revenue service vehicle requirement. The City has decided to run all of the buses, rather than parking the number not needed, in order to extend their useful life. The City determined that the desert heat would rapidly deteriorate the vehicles if they were just being stored and not active.

In addition to the deferral of implementing the new neighborhood service using small buses as mentioned above, other new services are also not being implemented as planned that called for operating 40-foot and 60-foot buses. Additionally, in July 2009, the City will again be cutting existing service due to funding constraints. This combination of service deferrals and cuts has resulted in a fleet-wide spare ratio in excess of 20%. At the direction of the Federal Transit Administration (FTA), the City is developing a new fleet management plan that will address how to deal with extra buses and, over time, trim down to a 20% ratio. This "trimming" will be accomplished through the retirement of 1998 vintage buses in 2010 (all 40-foot LNG). During the time that the City has the larger spare ratio, they believe they can save on operating costs and likely will not need as much mechanic overtime.

5. How have workforce constraints and the support of your advanced fuel systems and other on-board technologies challenged your maintenance programs in maintaining, servicing, and fueling your fleet?

The City's contractors have good retention of mechanics and technicians now. It is not as problematic as it has been in the past. Historically, contractors had difficulty finding qualified mechanics. The City has found, however, that the needed continuous training of mechanic/technicians has an impact on shop floor time. If the mechanics are in class, they are not available to work on buses.

Concerning the 60-foot buses (particularly the 20 with early vintage particulate traps), the City's contractor has a problem with mechanics not cleaning the filters frequently enough and properly diagnosing engine problems. For a long period there was only one trained mechanic that fully understood fuel injector and particulate trap problems and solutions.

As purchased transportation, it's up to the contractors to ensure that there is a sufficient, technically competent mechanic/technician work force. In the past, a contractor who couldn't sufficiently attract, retain, and train the necessary work force became an "ex-contractor."

Increased computerization requires the specialization of mechanics and technicians that can work on a variety of highly complex technology systems, such as fare collection apparatus, electronic head signs, digital cameras, automatic passenger counters, and on board voice annunciators. This is still a separate skill set from that required to work on an AVL system or a bus diagnostic computer system. The City and its contractors have found cross-training to be very challenging and difficult.

6. Please describe any special characteristics of your operating environment that place special demands on your peak and spare bus fleets (e.g., temperature extremes, snow and ice, urban congestion, topography, etc.)

In Phoenix, averages of 106 days per year exceed 100 degrees (Fahrenheit) and 17 days per year exceed 110 degrees. The heaters must function also. By the end of October high temperatures can reach 100 while the first of December can bring 40 degree low temperatures.

For the City's bus fleet, they specify the largest heating, ventilation, and air conditioning (HVAC) systems available with the heaviest duty compressors and condensers.

For their LNG buses, the fuel tanks are above the engine in the rear of the bus (where the HVAC unit is typically located). The HVAC unit has been moved (by design) to the top of the bus. This results in significant additional vibration that runs through the entire structure of the bus, from end to end. This vibration causes bolts and interior screws to shake loose throughout the bus (e.g. those fasteners holding up light panels, hose clamps, etc.) and must be retightened regularly. This results in additional maintenance time per bus.

All of the buses in the fleet run the air conditioning all the time. This has resulted in the need to shorten routes to let buses cool down. The extreme heat has a major impact on the entire bus, including hastened deterioration of engines and parts. In this region, dust intrusion also has a significant adverse impact on buses in the fleet. Dust gets into lights, gauges, and gaskets (even if sealed). Heat and dust intrusion requires significantly more preventive maintenance and damage repair in the Phoenix area than one might find at other transit agencies around the nation.

On average, air conditioning failures account for 30-50% of mechanical problems in the late spring-summer-early fall season. If the air conditioning is not functioning, then the vehicle is pulled from service immediately. It is not just a matter of passenger comfort, but life and death.

Streets in Phoenix are generally well taken care of, however, with recent budget problems, there has been some street deterioration (mainly washboarding and potholes) that have affected several buses on express lines. It could become a greater problem in the future.

7. What is the average annual vehicle mileage per bus for each subfleet you operate (this will be validating data provided in the survey)?

60-foot Articulated Bus:	37,500 average miles per bus
45-foot "Compo" Bus:	18,750 average miles per bus
40-foot Bus:	48,952 average miles per bus
30-foot Bus:	13,833 average miles per bus
Less-than-30-foot Bus:	40,086 average miles per bus

8. What is the average number of revenue hours per day per bus by subfleet?

60-foot Articulated Bus:	7.1 average hours/day per bus
45-foot "Compo" Bus:	3.6 average hours/day per bus
40-foot Bus:	9.3 average hours/day per bus
30-foot Bus:	2.6 average hours/day per bus
Less-than-30-foot Bus:	7.6 average hours/day per bus

9. Has your agency implemented specific policies, procedures, and/or practices aimed toward more efficiently managing your fleet and keeping spare bus requirements to a minimum?

The City's contractors do preventive maintenance and replacement of the HVAC systems year-round. They try to do as much as possible in the cooler off-season months to prepare the fleet for summer heat. The City also plans for more mechanic/technician overtime in the summer months to address air conditioning malfunctions and other heat-related system failures.

Conclusion

Overall, given the fleet mix, fuel types , on-board technologies, service mix requirements, and maintenance challenges, the City has found it very difficult to operate within a 20% spare ratio which has been in place since the 1960s. This has been exacerbated by the need to cut planned and existing levels of service which have immediately shifted vehicles from the peak requirement to spare status.

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APPENDIX E

INFORMATION OBTAINED FROM THE FTA RELATED TO THE BUS FLEET SPARE RATIO POLICY

Interpretation

1) Does your region view the 20% Spare Ratio Policy as a firm requirement to be enforced or a recommended guideline to be followed voluntarily by grantees?

FTA's spare ratio policy has been in existence for over 20 years. However, it is not in a statute or regulation. FTA implements the 20% spare ratio policy through its guidance circulars and grant management procedures.

2) Does your region apply the 20% Policy to both Fixed-Route fleets and Paratransit fleets, or Fixed-Route fleets only?

FTA's 20% spare ratio policy only applies to grantees operating 50 or more fixed-route revenue vehicles.

Enforcement Philosophy

3) If you view the policy as a requirement, how does your region enforce compliance?

For each grant application identified to acquire vehicles, a grant applicant must address the subjects of current spare ratio, the spare ratio anticipated at the time the new vehicles are introduced into service, disposition of vehicles to be replaced including information on age and mileage, and the applicant's conformance with FTA's spare ratio guideline. An applicant is required to notify FTA if the spare ratio computation on which the grant application is based is significantly altered prior to the grant award.

4) Has your region ever withheld grants due to a grantee's non-compliance with the 20% policy?

No. Spare ratio is reviewed for each grant application that includes an acquisition of vehicles. The basis for determining a reasonable spare bus ratio takes local circumstances into account, and FTA's regional offices verify that the spare ratio is reasonable prior to awarding the grant. The number of spare buses in the active fleet for grantees operating 50 or more fixed-route revenue vehicles should not exceed 20 percent of the number of vehicles operated in maximum fixed-route service. If a grant would make the grantees fleet exceed the spare ratio policy, and FTA determines that the proposed spare ratio is unreasonable, FTA will work with the grantee to adjust the grant application so that it only includes the purchase of an amount of vehicles that complies with the policy.

5) Does your region consider and grant waivers or variances to the 20% policy on a fleet-wide or sub-fleet basis? If so, for what reasons are waivers or variances granted?

Again, FTA would work closely with the grantee to ensure that they are in compliance with the spare ratio policy, thus eliminating the need to grant waivers or variances. The spare ratio policy allows for local circumstances to be taken into account. This flexibility means that there could be instances where FTA deems it reasonable to allow a higher spare ratio. For instance, a grantee wishing to use American Recovery and Reinvestment Act (ARRA) funds to purchase vehicles that would cause the grantee's fleet to exceed the applicable spare ratio requirements can work with the FTA regional office to determine what spare ratio will be reasonable and develop a plan for returning to the 20%.

6) Has your region ever allowed the special designation of sub-fleets (with a higher allowable spare ratio) for research and development, or other unique circumstances?

Spare ratio policy is only applicable to vehicles in fixed-route revenue service.

<u>Grantee Compliance</u>

7) Of the total grantees in your region, how many are out of compliance with the 20% Spare Ratio Policy?

The majority of FTA's grantees are in compliance with the 20% spare ratio policy, and those that aren't, we would work closely with them to develop a plan to bring them into compliance.

<u>Other</u>

8) Is there anything else related to the FTA Bus Fleet Spare Ratio Policy that might be useful to this research?

No.

APPENDIX F

REFERENCES

(1) *National Bus Spare Ratio Study*, by P. Branch, Federal Transit Administration, Office of Capital and Formula Assistance, Washington, DC, 1993.

(2) *TCRP Synthesis 11, System-Specific Spare Bus Ratios, A Synthesis of Transit Practice*, by J. Pierce, and E. Moser, Transportation Research Board, National Academy Press, Washington, DC, 1995.

(3) *2007 National Transit Database* (Web Site), Federal Transit Administration, Washington, DC.

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APPENDIX F

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Stephan A. Parker, Transportation Research Board (TRB), Senior Program Officer

Project Panel
Craig Allen, Capital Area Transportation Authority, Lansing, MI
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Capital Metro Transit Authority
Capital District Transportation Authority
Central Contra Costa Transportation Authority
Central Ohio Transit Authority
The Central New York Regional Transportation Authority

Centre Area Transportation Authority
Champaign-Urbana Mass Transit District
Charlotte Transit
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City of Shakopee
City of Torrance Transit System
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Duluth Transit Authority
Durham Area Transit Authority
Edmonton Transit
Everett Transit
Fayette Area Coordinated Transportation
Foothill Transit
Fort Bend County Public Transportation
Fort Worth Transportation Authority
Franklin Transit Authority
Fresno Area Express (FAX)
Gadsden Transportation Services
Galveston Island Transit
Gary Public Transportation
GDRTA (Dayton)

GO TRANSIT
Go West Transit
Gold Coast Transit
Golden Empire Transit
Golden Gate transit
Greater Cleveland Regional Transit Authority
Greater Lafayette Public Transportation Corporation
Greater Lynchburg Transit Company
Hampton Roads Transit
Hillsborough Area Regional Transit (HART)
Indianapolis Public Transportation (IndyGo)
Intercity Transit
Interurban Transit Partnership
Jacksonville Transportation Authority
Kansas City Area Transportation Authority
King County Metro
Kitsap Transit
La Crosse Municipal Transit
Lake Erie Transportation Commission
Lane Transit District
Lehigh and Northampton Transportation Authority
Link Transit
Long Beach Transit
Los Angeles County Metropolitan Transportation Authority
Luzerne County Transportation Authority
LYNX, Central Florida Regional Transit Authority
Maryland Transit Administration
Mass Transportation Authority
Memphis Area Transit Authority
Metro (Bi-State Development Agency)
Metro Transit
Metro Transit - Metropolitan Council
Miami Dade Transit
Mid Mon Valley Transit Authority (MMVTA)
Mid-Ohio Valley Transit Authority
Milwaukee County Transit System
Minnesota Valley Transit Authority
Modoc Transportation Agency / Sage Stage Bus
Monroe County Transit Authority (MCTA)
Montebello Bus Lines
Monterey-Salinas Transit
MTA - New York City Transit - Department of Buses

MTA Bus Company
Muncie Public Transportation Corporation
Nashville Metropolitan Transit Authority
Niagara Frontier Transportation Authority
North County Transit District
Northern Arizona Intergovernmental Public Transportation Authority (NAIPTA)
Norwalk Transit System
Oahu Transit Services, Inc
Omnitrans
Orange County Transportation Authority
Pace Suburban Bus
Palm Tran
Park City Municipal Corp.
Pierce Transit
Port Authority of Allegheny County
Potomac and Rappahannock Transportation Commission
Quad Cities Garage Policy Group
Redding Area Bus Authority
Regional Transportation District (Denver)
Riverside Transit Agency
River Valley Metro
Road Runner Transit
Rochester-Genesee Regional Transportation Authority
Sacramento Regional Transit District
Salem-Keizer Transit
San Diego MTS
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San Mateo County Transit District
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