Maintenance Technician Staffing Levels for Modern Public Transit Fleets

DETAILS

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 184

Maintenance Technician Staffing Levels for Modern Public Transit Fleets

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Administration and Management • Maintenance and Preservation • Public Transportation

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TRANSPORTATION RESEARCH BOARD

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TRANSIT COOPERATIVE RESEARCH PROGRAM

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

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FOREWORD

By Gwen Chisholm Smith
Staff Officer
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TCRP Report 184: Maintenance Technician Staffing Levels for Modern Public Transit Fleets identifies existing tools and practices used to determine optimum maintenance technician staffing levels and provides an analysis of variables that influence maintenance technician staffing needs. The report also documents the research team's development of an MS Excel-based Maintenance Staffing Calculator, a tool for managers of transit agencies of any size to use in estimating the optimal number of bus maintenance staff to meet current maintenance needs. It may also be used as a predictive tool, to determine staffing needs during the vehicle procurement process. The Maintenance Staffing Calculator is designed to help maintenance managers (1) break down staff by location or sub-fleet; (2) adjust raw employee numbers to full-time equivalents and available productive hours using information on current technician staffing, other employees contributing to maintenance, breaks, vacations, and shift information; (3) calculate preventive maintenance, core maintenance, and unscheduled maintenance task hours required by sub-fleet; (4) calculate heavy maintenance and repair hours required; (5) model effects on staffing of changes to fleet composition or usage; (6) model effects on staffing of changes to maintenance times or intervals, accounting for overtime required; and (7) compare results to a group of peer agencies. The Maintenance Staffing Calculator, a User Guide and a PowerPoint presentation summarizing TCRP Project E-10 are available on TRB.org by searching for "TCRP Report 184."

At one time, a simple measurement was used to determine whether a transit agency had adequate maintenance technician staff—a basic bus-to-mechanic ratio. If an agency had four or five buses per mechanic, it was considered to have an excellent bus-to-mechanic ratio. That formula is clearly from a time when engines were less complex, most fleets were using diesel fuel, and computers were not an essential mechanic tool. Today, a computer is as essential as a socket wrench and the number of maintenance technicians needed to maintain a modern fleet can be difficult to measure. The number of maintenance technicians at a transit agency is based on financial constraints, fleet age, annual miles, powertrain type, how much work is outsourced, and a multitude of other key factors. There is no "textbook" formula for maintenance managers trying to determine the optimum ratio of maintenance technicians for their fleet size, as the number varies tremendously among public transit fleets. Many public transit buses are in service well beyond the FTA minimum requirement of 12 years, 500,000 miles. Transit agencies replacing buses are faced with significant leaps in technology over the past 6 to 12 years and now can purchase clean diesel and hybrid engines and choose among various alternative fuels—all of which require highly skilled technicians. In addition, today's new engines require preventive maintenance every 3,000 miles, half the rate of the older, simpler engines. With new labor-intensive engines, various fuel types, highly sophisticated electronics, and an increase in preventive maintenance frequencies, many maintenance managers realize they need to hire additional staff. The results of this research provide a resource to help maintenance managers evaluate staffing requirements to maintain an aging, high-mileage fleet or to transition into new technology hybrid or battery-powered engines.

EDSI Consulting prepared this report under TCRP Project E-10. The primary objective of this research was to produce an interactive staffing tool for use in determining optimum maintenance technician staffing levels for small, medium, and large public transit bus and other revenue fleets. To accomplish this objective, a review of fleet and staffing data from 321 transit agencies in the National Transit Database were analyzed, and two rounds of in-depth interviews with transit agencies were conducted to identify main factors driving technician staffing levels.

In addition to these data-gathering efforts, the research team developed the Maintenance Staffing Calculator, an MS Excel-based tool to help transit systems of various sizes determine the optimum number of maintenance technicians required to maintain a modern public transit fleet.

CONTENTS

SUMMARY

Maintenance Technician Staffing Levels for Modern Public Transit Fleets

As transit bus technology continues to advance, the tools used to define maintenance staffing levels must also advance. Often the number of maintenance technicians at a transit agency is based on financial constraints, fleet age, annual miles, powertrain type, how much work is outsourced, and a multitude of other key factors. There is no "textbook" answer for maintenance managers considering how to determine the optimum ratio of maintenance technicians to fleet size, as the number varies tremendously among public transit fleets. With the many fleet variables and alternative fuels, it is difficult to compare staffing levels among public transit fleets. There is no standardized guidance to help maintenance managers evaluate staffing requirements for maintaining an aging, high-mileage fleet or for transitioning into new technology such as hybrid or battery-powered engines.

An initial goal of the research reported herein was to identify how these various factors interact with maintenance time and staffing requirements and to determine whether there was a predictive or prescriptive staffing formula in use explicitly or implicitly among agencies. After analyzing a substantial amount of fleet and staffing data from the 2010 National Transit Database (NTD) and conducting two surveys of 68 agencies, the research team concluded that while there are some small and large correlations at work, there is no single formula or combination of formulas that can predict or describe an appropriate staffing level given a set of fleet composition data. There are just too many unique local variables at play.

Given this finding, the approach to the research changed. The research team developed the Maintenance Staffing Calculator, which starts from the ground up identifying each subfleet's specific maintenance requirements; determining total number of hours for preventive, scheduled, and unscheduled maintenance and heavy repairs; and distributing those hours, given local work requirements, to identify a necessary staffing level.

TCRP Project E-10 took an analytical approach to creating the Maintenance Staffing Calculator. Research began with analyzing existing data from the 2010 NTD to identify the main factors driving technician staffing levels. For this data set, agency size, duty cycle, and spare ratio all had some significant correlations with one or more measures of staffing level (number of maintenance employees and hours used per vehicle, per vehicle hour, and per vehicle mile). Larger agencies generally had higher maintenance staffing levels on a per-vehicle and per-mile basis. This made intuitive sense as those agencies are more likely to run larger, more complicated vehicles and to in-source some heavy repairs and overhauls. The data also showed lower average miles per hour for a fleet—indicative of an urban, stop-and-go duty cycle—correlated with higher staffing levels. Finally, the smaller the spare ratio in a fleet, the higher the level of staffing found on a per-vehicle and per-mile basis. The detailed results of this analysis are included in Chapter 1 of this report.

While all of these correlations made intuitive sense, there were significant ranges of results in all cases and plenty of examples where, on a local level, these correlations did not hold.

The research team set out to determine whether further factors could be identified and clarified with customized surveys.

The research team developed a questionnaire to survey transit agencies on their current maintenance practices. Data were gathered from 68 diverse transit agencies (for 27 agencies, data were gathered through site visits; the rest of the data were gathered through an online survey) in response to an extensive set of questions in the following areas:

- Agency profile and service data
- Maintenance facilities
- Fleet inventory
- Maintenance practices
- Workforce titles, roles, and hours/labor policies
- Training practices

There was an enormous range in number of maintenance hours per year per vehicle across the agencies (see Table S-1).

By separating out heavy repairs, which are not performed by every agency, the research team hoped to arrive at a narrower range in the numbers of maintenance staff required to maintain equivalent fleets for operation. However, even after separating out heavy maintenance, there was still a wide range in agency staffing levels for performing the core fleet maintenance common to every agency. The research team looked at the data from various perspectives—fleet size, fleet characteristics, maintenance practices, and training practices—to try to understand the driving factors of the staffing ratios. While there were some identified correlations for fleet size and makeup, the main conclusion was that there was no clear set of factors that could be combined to predict staffing levels. Further detail on the survey development process, agency characteristics, and analysis of data from the 68 agencies can be found in Chapter 2.

The Maintenance Staffing Calculator is designed to help maintenance managers do the following:

- Break down staff by location and/or sub-fleet
- Adjust current staff to full-time equivalents (FTEs) and available productive hours using information on current technician staffing; other employees contributing to maintenance; and data on breaks, vacations, and shifts
- Calculate preventive maintenance, core maintenance, and unscheduled maintenance task hours required by sub-fleet
- Calculate heavy maintenance and repair hours required

Table S-1. Means and standard deviations of maintenance technician hours per year per vehicle.

	Technician hours per year per vehicle maintained (n=57)	
Types of maintenance hours	Mean	StDev
Core maintenance	290.7	121.2
Adjustment for in-house heavy repair	46.9	51.5
Mechanic helpers or apprentices	11.5	24.8
Total maintenance hours	**349.1**	**155.7***

*Standard deviations of subsets don't necessarily sum to the standard deviation of the whole group.

- Model changes to fleet composition or usage
- Model changes to maintenance times or intervals
- Account for overtime required
- Compare results to a group of peer agencies

The Maintenance Staffing Calculator and the Maintenance Staffing Calculator User Guide include all of the elements listed above and are very flexible: they can be used by all types of agencies for very detailed analysis or to provide quick snapshots.

CHAPTER 1

Analysis of the National Transit Database and Other Data

Process

The research team used the 2010 National Transit Database (NTD) as the core data source for the initial review of maintenance staffing–related data. Although the Maintenance Staffing Calculator and Maintenance Staffing User Guide (User Guide) are usable by agencies of all sizes, for the purpose of this analysis, the data set was limited to the 433 agencies with fixed-route transit bus operations and fleet size (measured by vehicles operated for maximum service [VOMS]) greater than 10 vehicles. The staffing ratios of agencies with fewer than 10 vehicles were excluded because of the outsized effect that adding or subtracting a single staff member at those agencies would have on the calculations.

Among the 433 agencies in the data set, there were 112 agencies who did not submit to NTD either the number of maintenance employees and/or the number of maintenance hours. This left 321 agencies for analysis. For these agencies, the research team calculated the following expressions of staffing levels:

- Maintenance hours per 10,000 vehicle revenue miles
- Maintenance hours per 10,000 vehicle revenue hours
- Annual maintenance hours per revenue vehicles operated
- Annual revenue miles per maintenance employee
- Annual revenue hours per maintenance employee
- Revenue vehicles per maintenance employee

The research team reviewed the NTD for possible independent variables to analyze for their effects on the staffing variables listed above. Agency size, duty cycle, and spare ratio were identified as items with possible correlation and predictive value to the staffing ratios. Analysis of mean distance between failures was excluded because it seemed clear that there was no consistent definition of, nor reporting on, what constituted a failure among the respondents to the NTD.

Overall Characteristics of the Data Set

The median and average measures of maintenance staffing levels at the 321 agencies are shown in Table 1.

The data set included agencies of all sizes (see Table 2).

Effects of Agency Size on Maintenance Staffing Levels

There were clear positive correlations between agency size and all measures of staffing ratios, as can be seen in Figures 1 through 6. The larger the agency, as measured by number of vehicles operated, the more maintenance employees and hours used per vehicle, vehicle hours, and vehicle miles. This makes intuitive sense as larger agencies are more able to in-source maintenance and perform heavy repairs and overhauls. Analysis performed in this research separated out core maintenance tasks from supplemental maintenance to determine whether there was a different level of expected efficiency in maintenance given an agency's size. Although there are clear trends, in each subgroup (by agency size) there are a number of exceptions with extraordinarily high or low staffing levels. (This can be seen in the Min/Max bars in the figures). So, there are clearly other factors influencing staffing levels.

Effects of Duty Cycle on Maintenance Staffing Levels

Annual revenue miles and annual revenue hours reported to NTD were used to calculate fleet average miles per hour as a proxy for the typical duty cycle of the agency's fleet. The research team hypothesized that lower average miles per hour—indicative of an urban, stop-and-go duty cycle—would correlate with higher necessary staffing levels. Results of the analysis are shown in Figures 7 through 12.

Table 1. Median and average measures of maintenance staffing levels at 321 transit agencies.

Maintenance Staffing Levels	Median	Average
Maintenance Hours per 10,000 Vehicle Revenue Miles	191.0	231.0
Maintenance Hours per 10,000 Vehicle Revenue Hours	2,604.0	3,183.0
Annual Maintenance Hours per Revenue Vehicles Operated	758.0	832.0
Annual Revenue Miles per Maintenance Employee	95,351.0	143,594.0
Annual Revenue Hours per Maintenance Employee	6,736.0	10,191.0
Revenue Vehicles per Maintenance Employee	2.40	3.47

Table 2. Distribution by size of the 321 agencies analyzed.

Agency Size	Total
>1,000 Buses	8
500–999 Buses	12
250–499 Buses	18
100–249 Buses	45
50–99 Buses	48
25–49 Buses	86
10–24 Buses	104
Grand Total	321

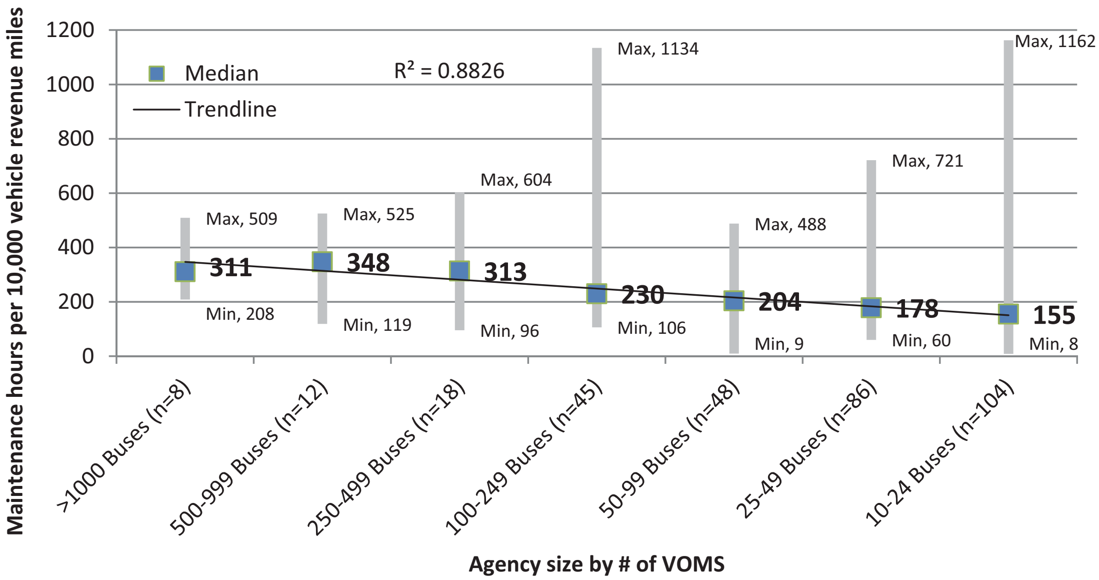


Figure 1. Maintenance hours per 10,000 vehicle revenue miles by agency size, 2010.

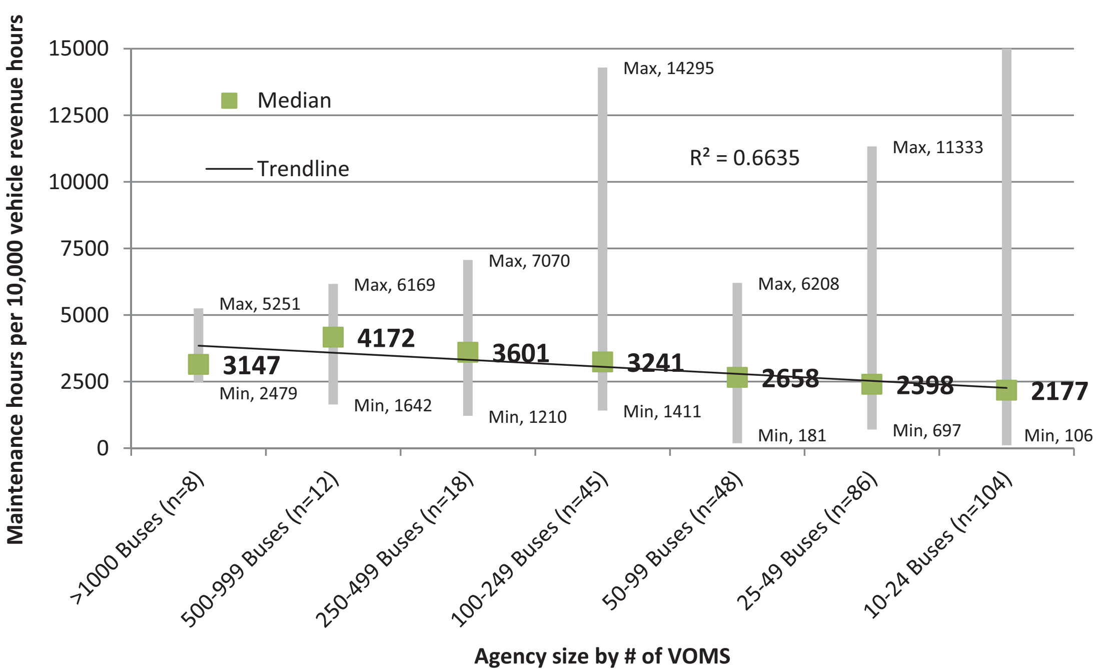


Figure 2. Maintenance hours per 10,000 vehicle revenue hours by agency size, 2010.

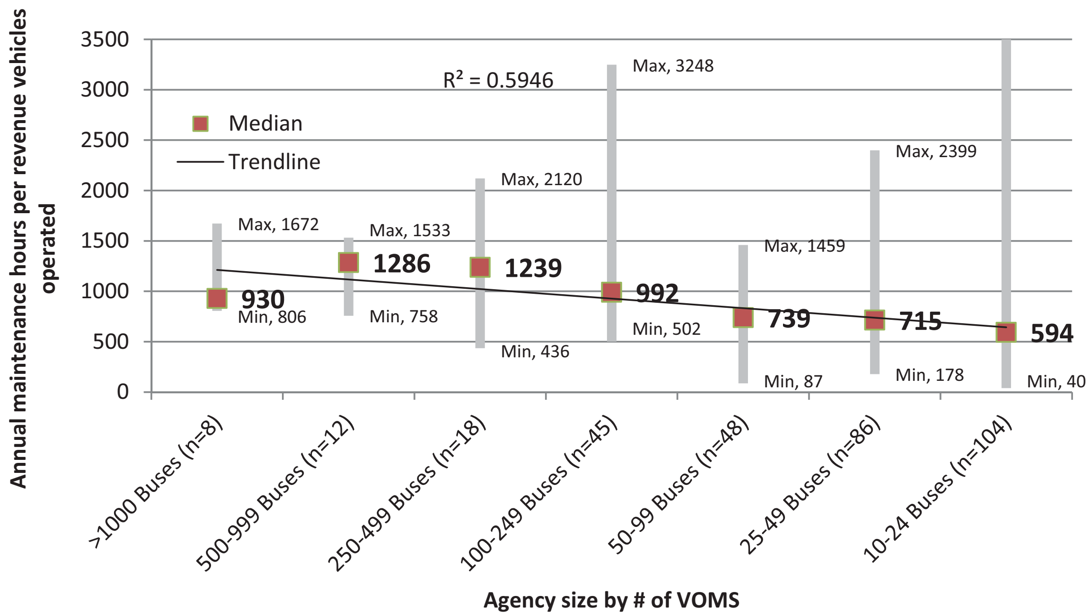


Figure 3. Annual maintenance hours per revenue vehicles operated by agency size, 2010.

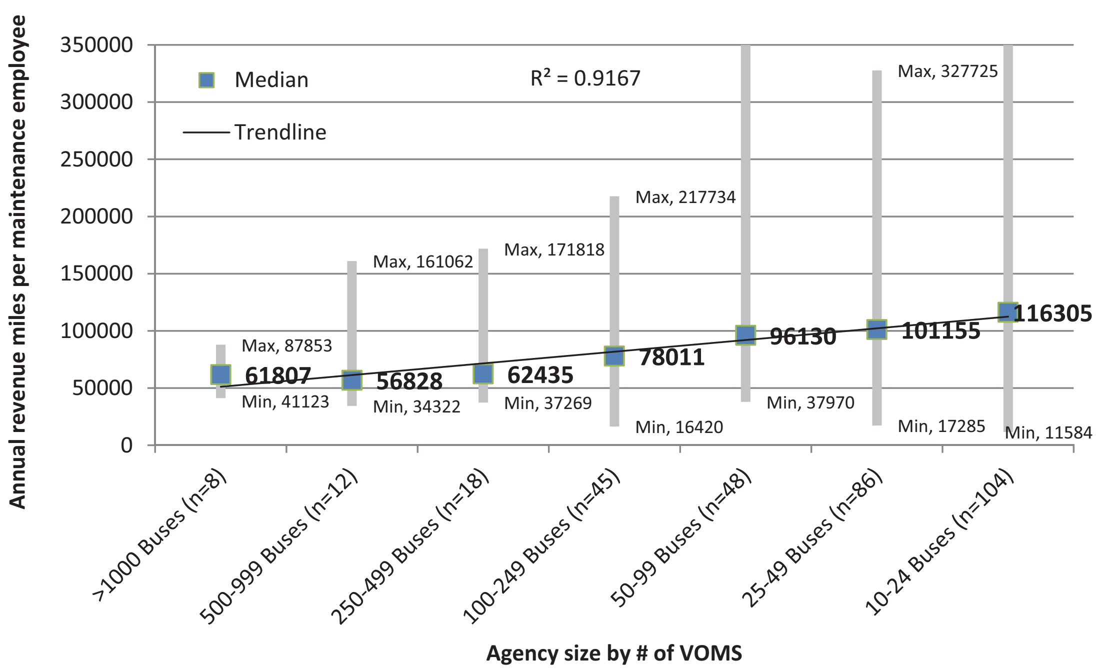


Figure 4. Annual revenue miles per maintenance employee by agency size, 2010.

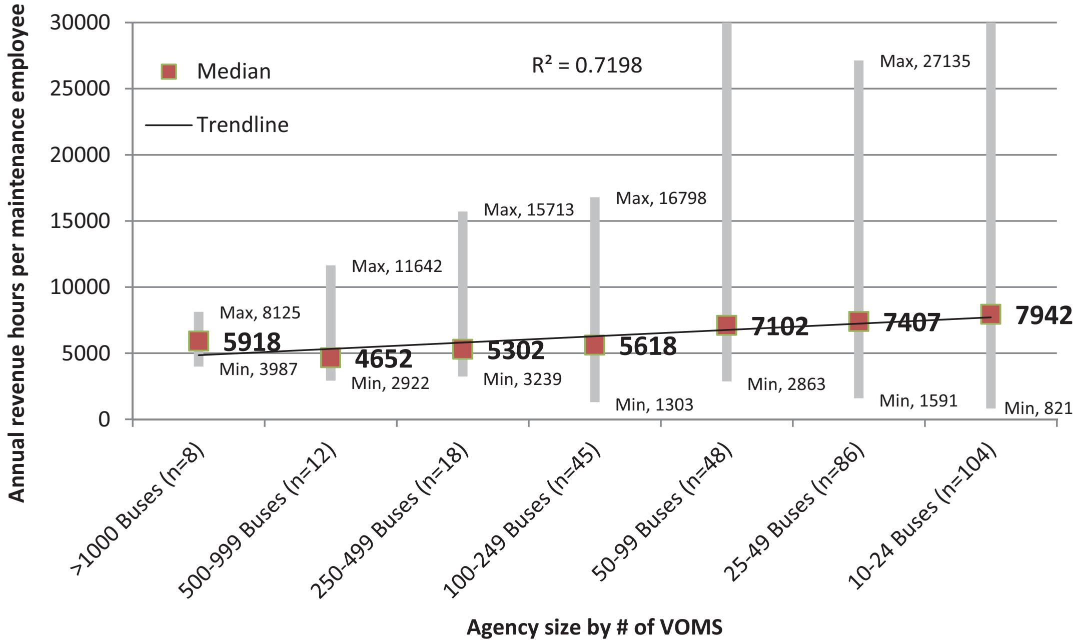


Figure 5. Annual revenue hours per maintenance employee by agency size, 2010.

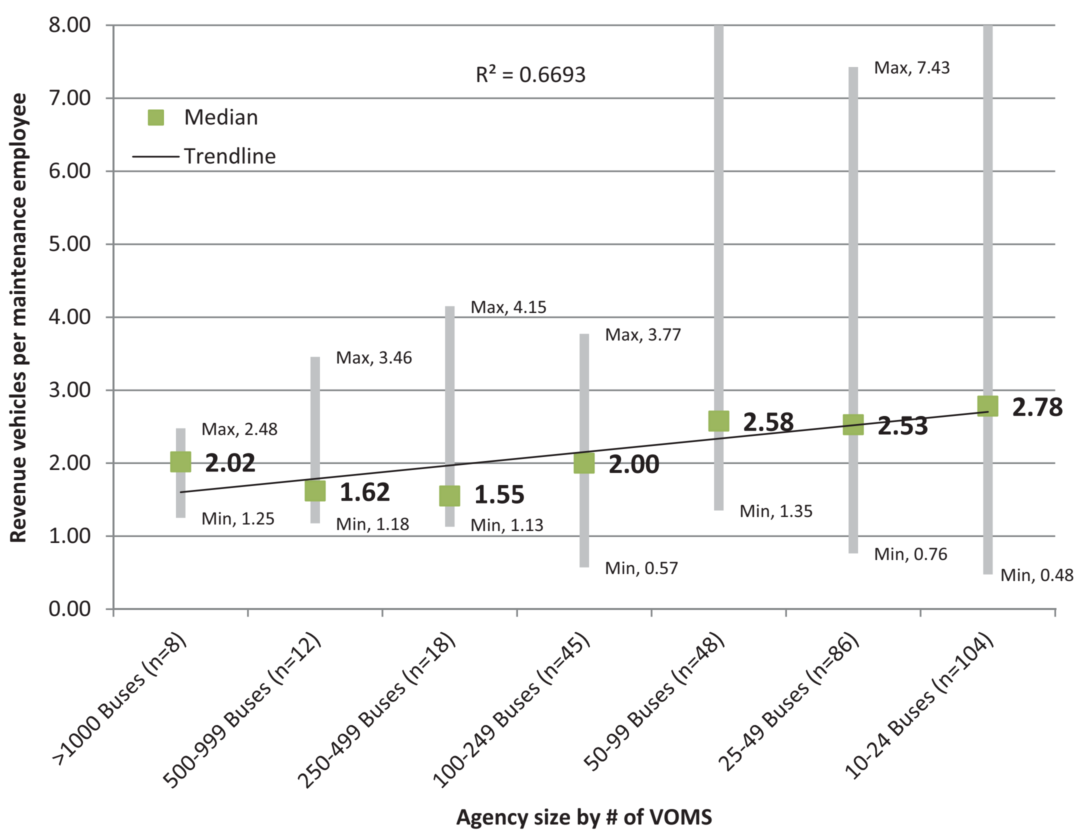


Figure 6. Revenue vehicles per maintenance employee by agency size, 2010.

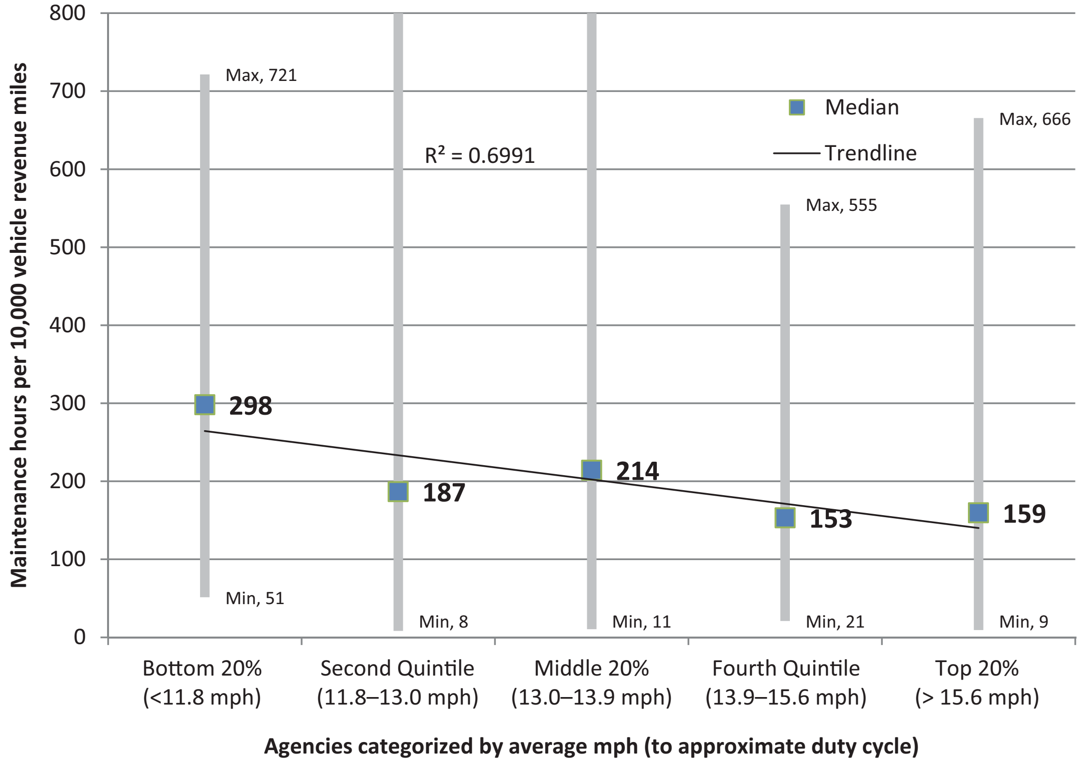


Figure 7. Maintenance hours per 10,000 vehicle revenue miles by agency average mph, 2010.

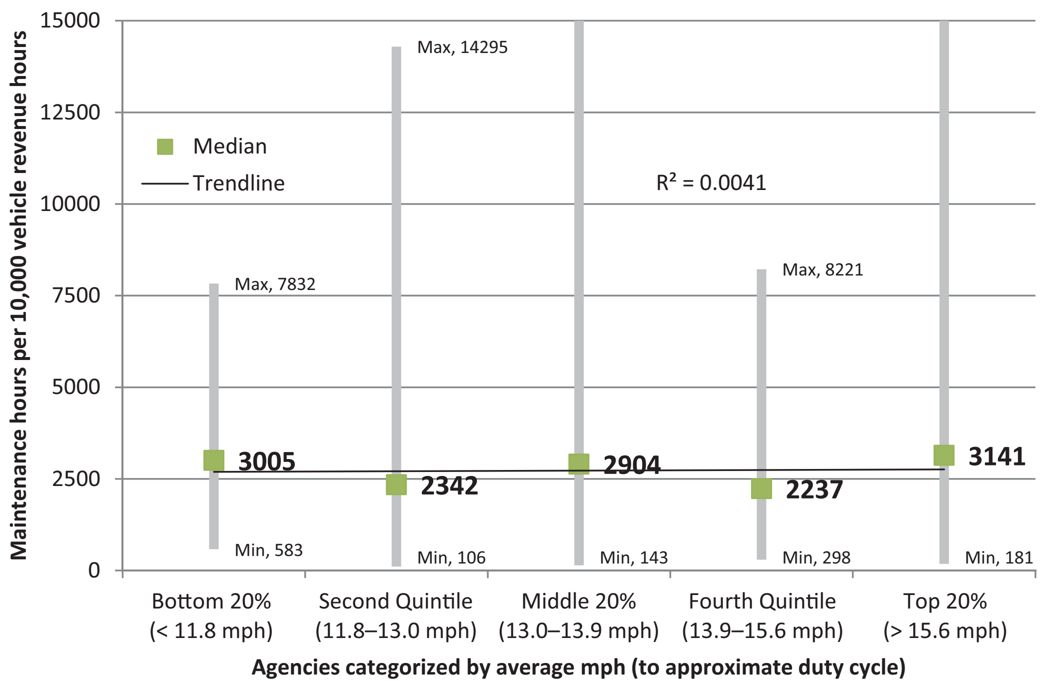


Figure 8. Maintenance hours per 10,000 vehicle revenue hours by agency average mph, 2010.

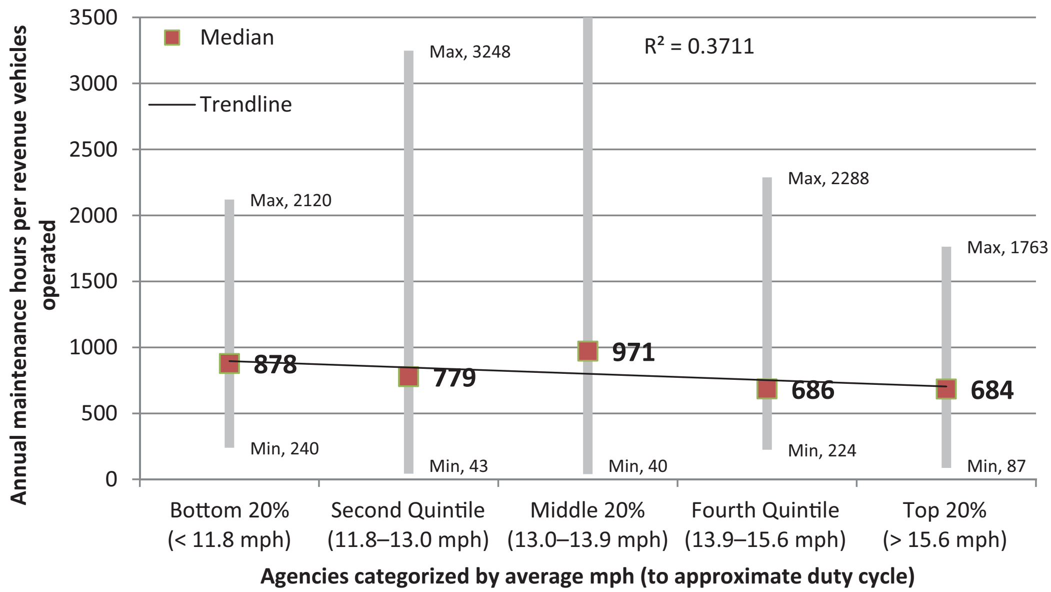


Figure 9. Annual maintenance hours per revenue vehicles operated by agency average mph, 2010.

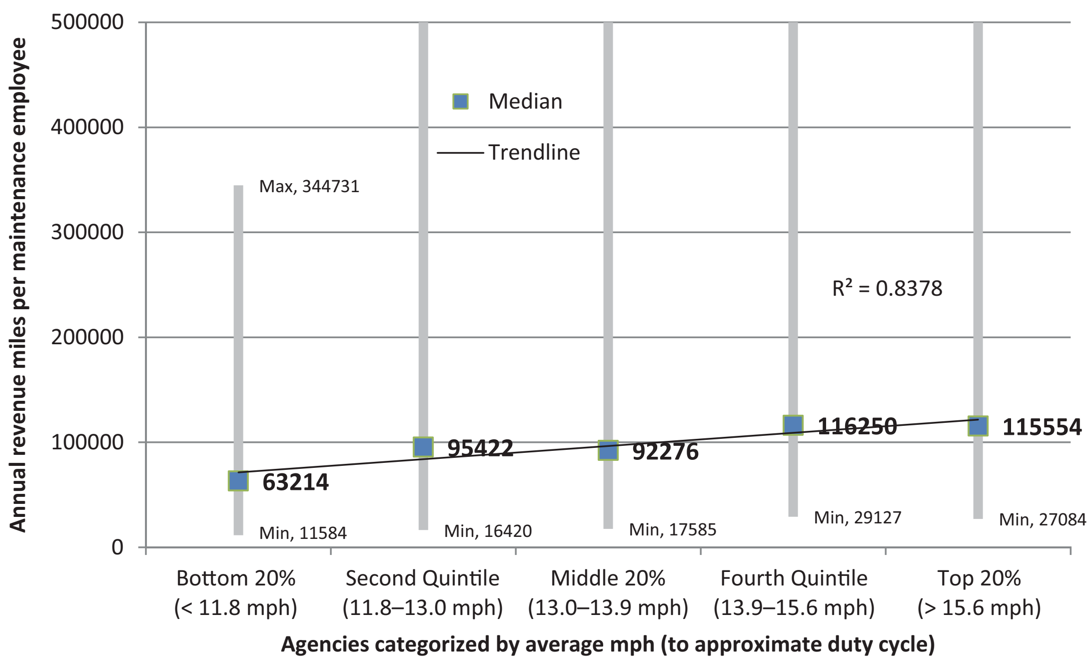


Figure 10. Annual revenue miles per maintenance employee by agency average mph, 2010.

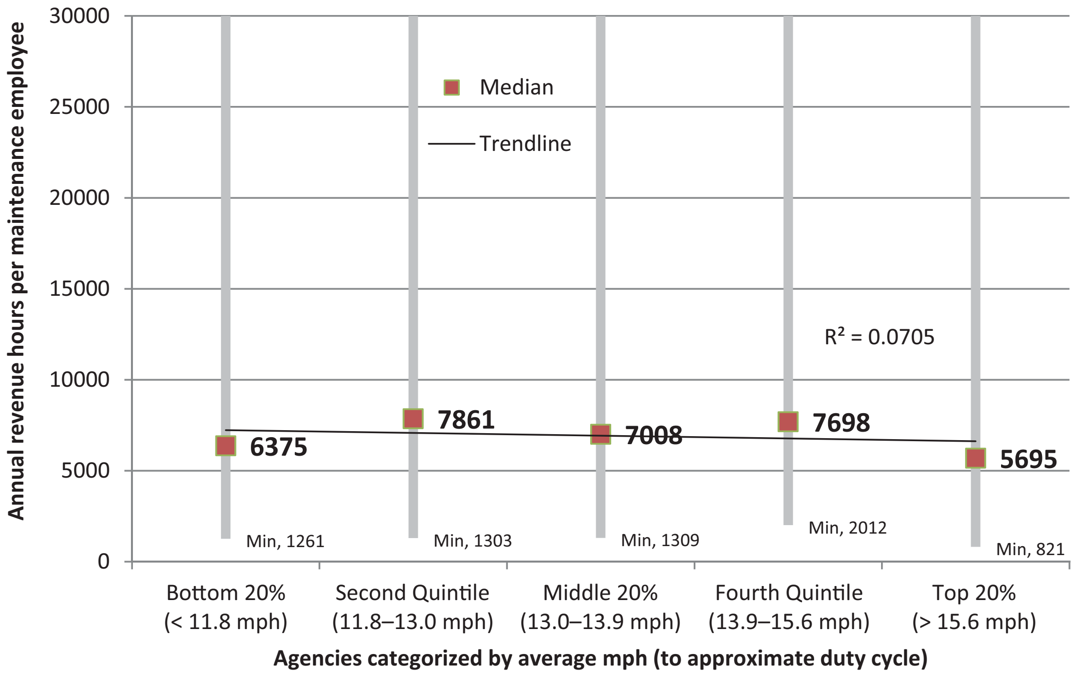


Figure 11. Annual revenue hours per maintenance employee by agency average mph, 2010.

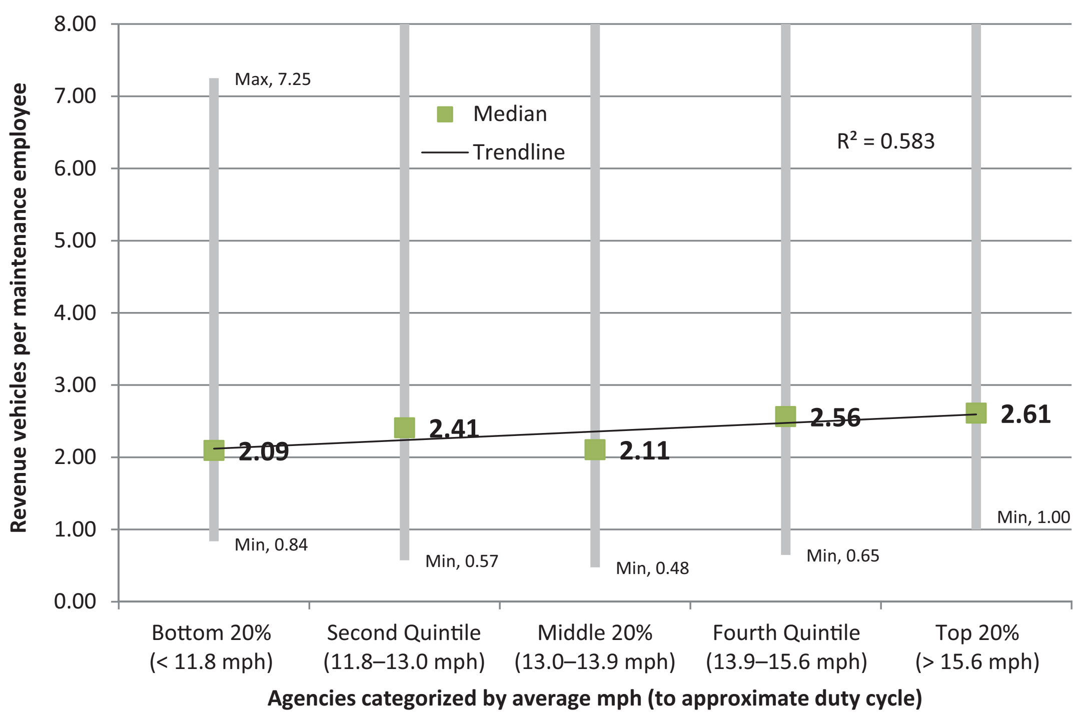


Figure 12. Revenue vehicles per maintenance employee by agency average mph, 2010.

The correlation predicted appeared by comparing measures of revenue miles and number of vehicles, but not revenue hours. In other words, a more urban duty cycle indicates a generally high staffing level when measured by maintenance hours per vehicle mile (or per vehicle), but the effect is canceled out when looking at vehicle hours (there are fewer hours to achieve higher miles at urban duty cycle agencies).

Effects of Spare Ratio on Maintenance Staffing Levels

It was predicted that a higher spare ratio would allow for a relatively lower staffing level, as the protection of spare vehicles allows for some maintenance to be delayed or certain shifts to not be covered as extensively. The spare ratio was calculated by subtracting VOMS from vehicles available for maximum service (VAMS) reported to NTD and dividing the difference by VOMS. Figures 13 through 18 show the effect of the spare ratio.

Measuring Correlation of Variables with Maintenance Staffing Levels

As Figures 1 through 18 show, the major conclusion of this analysis of the NTD data is that there are unknown drivers at work when agencies determine their maintenance staffing levels. Although the independent variables selected showed correlations with the staffing levels, the reasons for those correlations are not clear. Additionally, although there are trends and tendencies, the range of ratios is quite broad, even among agencies that appear to be similar in size, duty cycle, and spare ratio. In order to examine the actual determinants of maintenance staffing levels at transit agencies, the research team undertook a data-gathering effort.

An R^2 ("R-squared") value is a measure of how much variance in a dependent variable is accounted for by a given independent variable. The R^2 values shown in Figures 1 through 18 (summarized in Table 3) are the result of a linear regression formula that determines the percentage of variance in a dependent variable (the various expressions of staffing levels for each quintile of agencies) that is accounted for by an independent variable (agency size, duty cycle, or spare ratio). These R^2 values are based on the "average of averages" displayed in each figure and not on a full linear regression of the data set. If a full linear regression were performed, the R^2 values would be much lower. The NTD data were analyzed to discover initial and general trends and correlations. The research team used the results of this analysis to design a survey instrument that would help uncover the cause(s) of these trends and correlations.

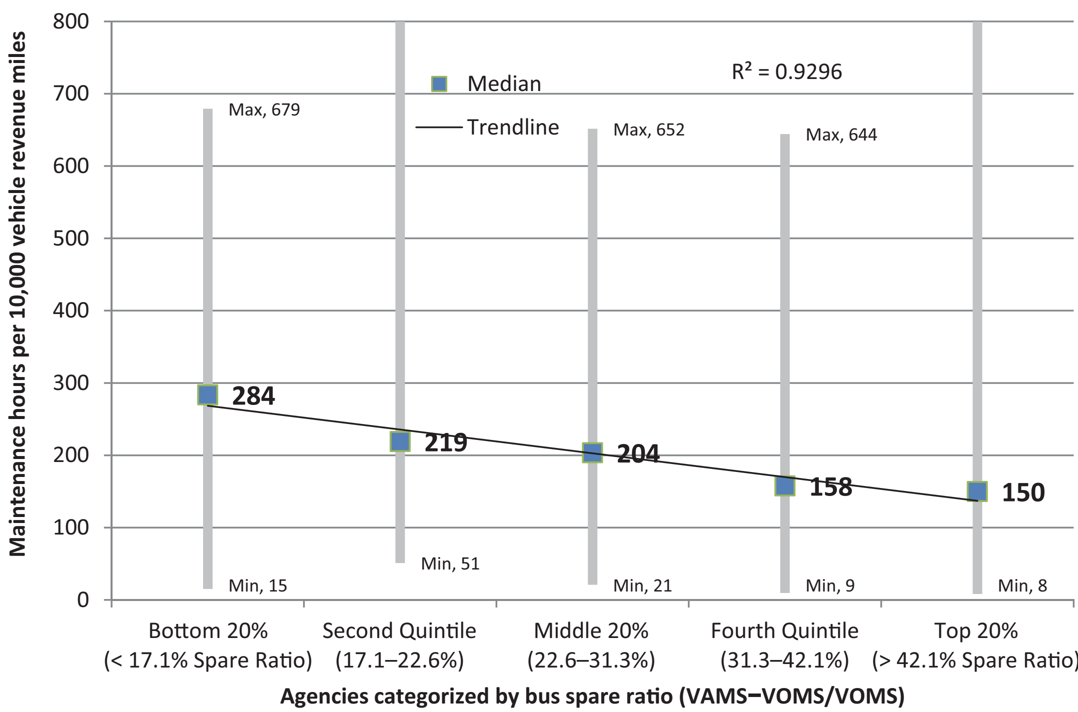


Figure 13. Maintenance hours per 10,000 vehicle revenue miles by bus spare ratio, 2010.

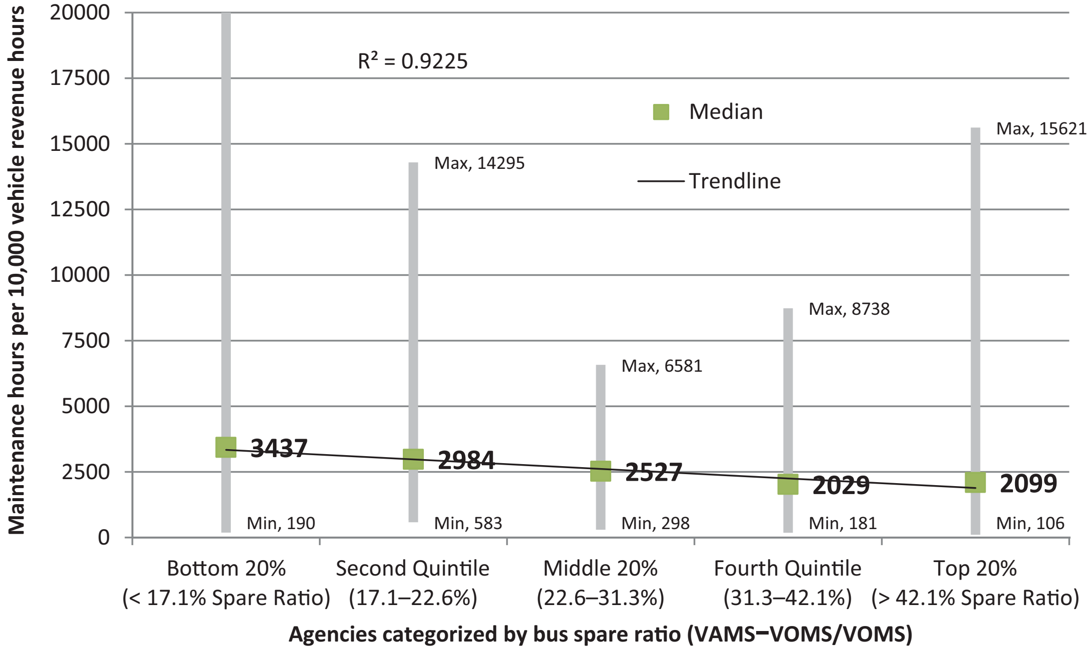


Figure 14. Maintenance hours per 10,000 vehicle revenue hours by bus spare ratio, 2010.

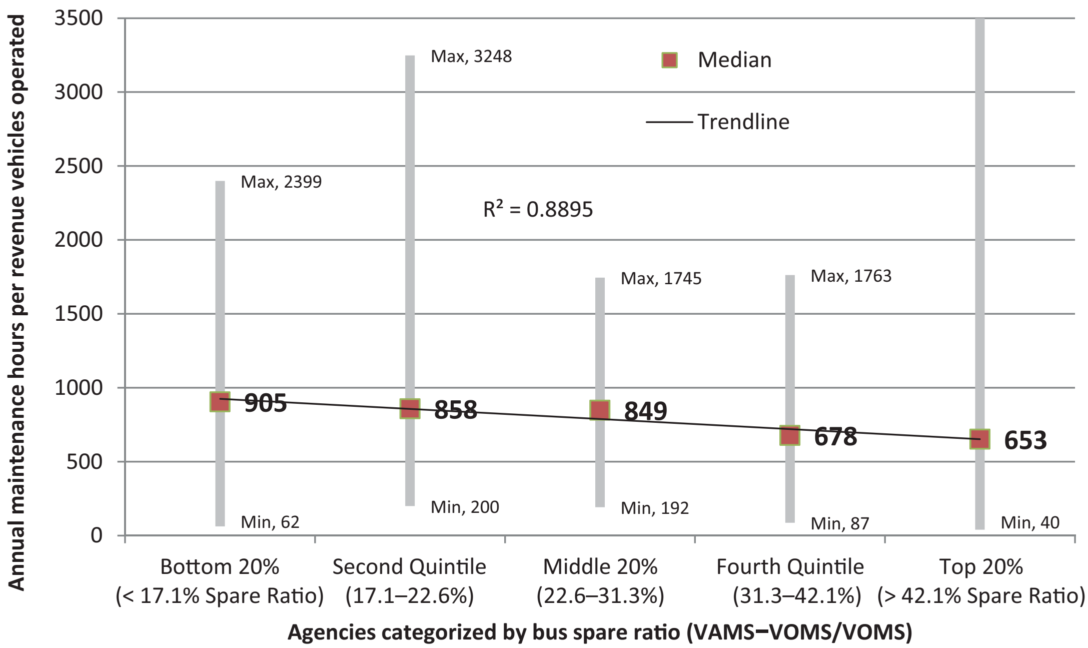


Figure 15. Annual maintenance hours per revenue vehicles operated by bus spare ratio, 2010.

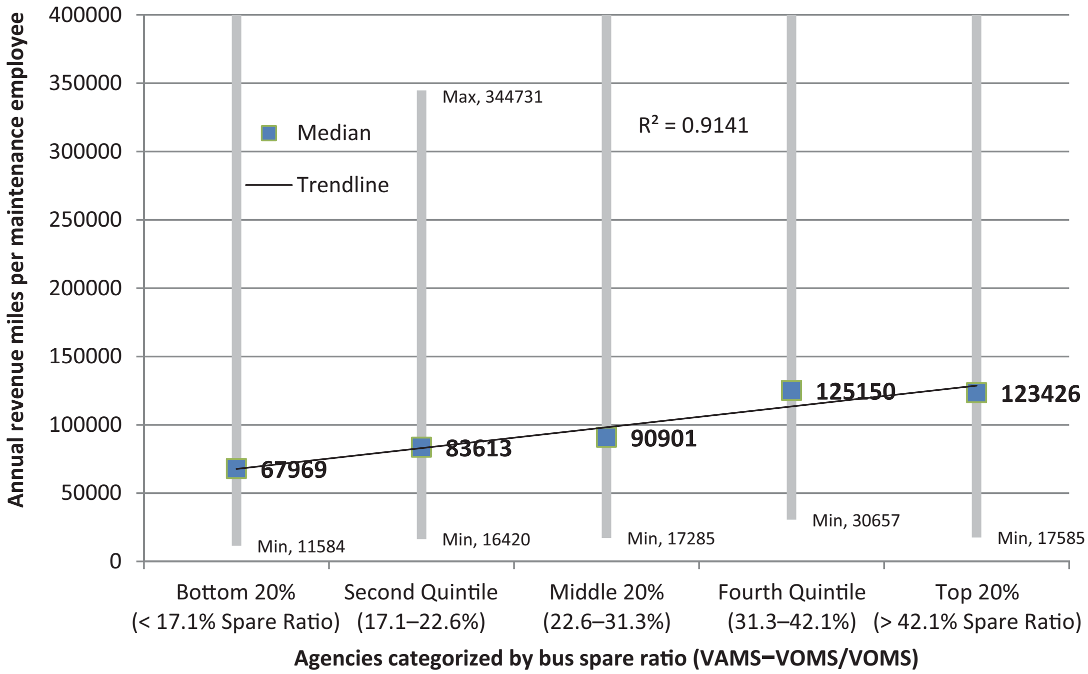


Figure 16. Annual revenue miles per maintenance employee by bus spare ratio, 2010.

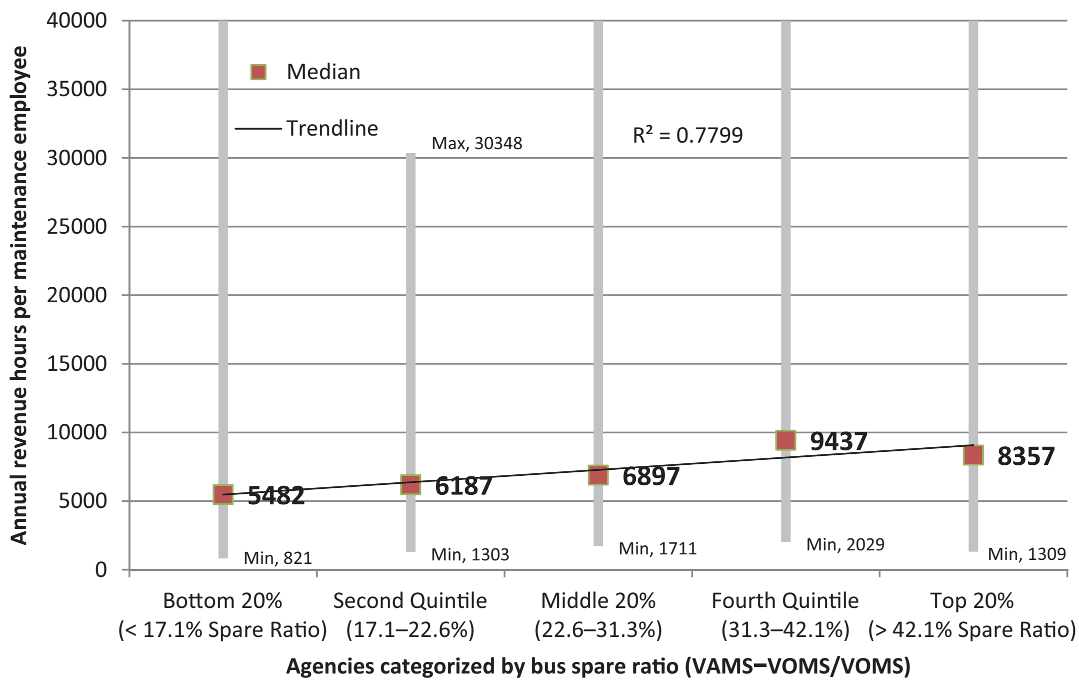


Figure 17. Annual revenue hours per maintenance employee by bus spare ratio, 2010.

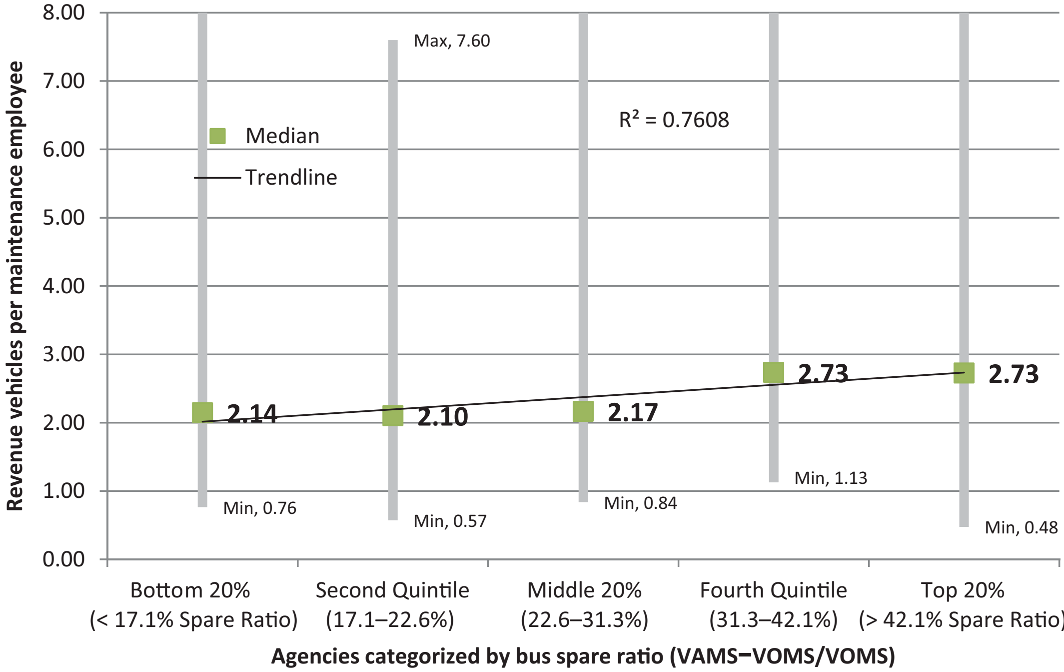


Figure 18. Revenue vehicles per maintenance employee by bus spare ratio, 2010.

Table 3. R^2 values for 2010 NTD data (321 agencies with >10 vehicles operated).

Dependent Variables	Independent Variables		
	Agency Size	Duty Cycle	Spare Ratio
Maintenance Hours per 10,000 Vehicle Revenue Miles	0.88	0.70	0.93
Maintenance Hours per 10,000 Vehicle Revenue Hours	0.66	0.004	0.92
Annual Maintenance Hours per Revenue Vehicles Operated	0.59	0.37	0.89
Annual Revenue Miles per Maintenance Employee	0.92	0.84	0.91
Annual Revenue Hours per Maintenance Employee	0.72	0.07	0.78
Revenue Vehicles per Maintenance Employee	0.67	0.58	0.76

CHAPTER 2

Analysis of Maintenance Staffing and Practice at Selected Agencies

The NTD data analyzed provided an aggregate number of maintenance hours at each transit agency. The NTD data are not broken down by hours, type of maintenance performed, type of vehicles in the fleet, service profiles, and other significant defining factors. The next step in the research process was to conduct interviews at a group of transit systems of various sizes and in different geographic locations to collect pertinent data on factors that could affect maintenance staffing.

First Round of Data Collection—Initial Questionnaire

For the first round of data collection, the research team began considering all the possible variables that could go into determining staffing levels and developed a very detailed questionnaire. This initial questionnaire has six major parts: Agency Profile and Service Data; Profile of Maintenance Facilities; Fleet Inventory; Maintenance Times/Requirements; Maintenance Workforce Titles, Roles, and Hours; and Training Practices. The content of the initial questionnaire and the justification for pursuing each type of data are explained below.

Agency Profile and Service Data

This section of the initial questionnaire gathered data about vehicle inventory by modes (e.g., bus, bus rapid transit, commuter bus, trolley bus, and demand response). For each mode, several types of data were identified: number of available vehicles, number of operated vehicles for service, average age of vehicles, annual revenue vehicle miles, annual revenue vehicle hours, and passenger trips.

The initial questionnaire also identified whether any portion of the transit fleet was not maintained directly by transit agency employees. Correctly matching staffing levels with the vehicles actually being worked on was a strong consideration in developing this instrument. The research team believes that there are cases where staffing ratios are inaccurately reported because, for instance, one group of employees may be performing maintenance on non-transit vehicles or another group may only maintain a portion of the overall fleet. Efforts to clearly define the scope of maintenance work and the associated maintenance staff at each agency were critical to developing a valid Maintenance Staffing Calculator and User Guide.

Profile of Maintenance Facilities

Information on the number of maintenance facilities and the type of work done at each facility was gathered in this questionnaire section. The fleet types identified in the agency profile are broken down by facility, and the staffing level (full-time equivalent [FTE] maintenance staff) at each facility was also identified. This information can help to identify whether different types of fleets or modes lead to different staffing ratios within a given agency. Another critical question addressed in this section was identifying facilities fully dedicated to heavy repair and overhaul. The hours and staff exclusively dedicated to these activities were separated out for analysis in order to compare agencies that outsource these activities with those that do not.

Fleet Inventory

A detailed breakdown of vehicles by manufacturer, year, and size was sought. The facility location of each vehicle was also identified. Vehicle age was anticipated to be a driver of maintenance requirements and staffing needs, but the manufacturers were also analyzed to see whether there would be a correlation between manufacturer and staffing level or whether lower staffing levels would be found at agencies with fewer distinct types of vehicles. The research team also tracked the number of articulated vehicles, which normally have higher maintenance requirements.

Maintenance Times and Requirements

This was the most extensive part of the data-gathering process. The initial questionnaire broke down actual maintenance times at each agency by type of maintenance activity and vehicle type. Core maintenance activities were identified and separated out (preventive maintenance inspections [PMI] at various intervals, various other scheduled maintenance such as brake relines or follow-up repairs for items identified in PMI, special campaigns, seasonal work, etc.). Unscheduled maintenance and repairs were also separated out. Any heavy repair and overhaul such as body work, machining work, and small component and major unit rebuilds were also identified. The total hours for maintenance support work, such as daily service line functions and administrative support, were also included. In the analysis, the research team divided staffing into a "core ratio" and a "supplemental ratio." The core ratio is the amount of running maintenance staff time needed to actually run the fleet, and the supplemental ratio is the additional time required to perform overhaul and rebuild work in house. This made it easier to compare agencies of similar size and better determine the significance of the difference in staffing levels between agencies.

A number of questions were asked to understand each agency's approach to maintenance. Preventive maintenance practices and what maintenance is defined as "preventive" were identified. Looking at what percentage of overall maintenance time is dedicated to preventive maintenance and what percentage of preventive maintenance is completed on time, could provide valuable data for understanding whether preventive maintenance scheduling and follow through lead to lower staffing levels.

The initial questionnaire identified the major drivers of unscheduled maintenance and what percentage of overall time the top unscheduled items account for at each agency. The mean distance between failures was also identified, along with how the agency defines a failure for this measurement. This helped determine what effect vehicle reliability had on the reported staffing levels.

Finally, questions were asked on what methods the agency uses to set its current staffing level, if the agency feels staffing is adequate, and what it would do with a staffing level increase of 10%.

Maintenance Workforce Titles, Roles, and Hours

After distinguishing the various types of maintenance activities, it was necessary to analyze maintenance staff job responsibilities to determine which job titles include which work. At some agencies, a portion of a maintenance technician's time is spent on facility maintenance, bus cleaning, or service line functions. At other agencies, staff who perform this work have separate job titles. Conversely, sometimes staff with non-"technician" job titles are actually performing transit vehicle maintenance. These distinctions must be accounted for in order to compare staffing levels at different agencies in a meaningful way. The matrix in this section of the initial questionnaire identifies staff, job titles, and percentage of time spent on various responsibilities. The FTEs in various types of maintenance were determined by calculating weighted averages of numbers in each job title and the distribution of work in each job title.

This section of the initial questionnaire also identifies the available hours per employee. Two agencies that require the same number of maintenance hours may have differing vacation and sick leave policies, which would mean that each agency would require a different number of technicians to meet the same level of need for maintenance hours. Identifying available hours helps in determining an appropriate staffing level given local collective bargaining and other policies.

Training Practices

The project team sought to identify any relationship among staffing levels, investment in maintenance training, and mechanic skill level. A detailed set of data on the number of hours of training provided for maintenance technicians was gathered. The initial questionnaire distinguishes among original equipment manufacturer training for new vehicles, targeted skill-building training, and in-house training. Information on in-house training staff, existing training programs, and apprenticeships is also identified. Data on the number of training hours were analyzed in conjunction with the reported skill levels of current technicians for the agencies participating in the Skilldex analysis performed in a later stage of the research.

Data Collection Issues—Initial Questionnaire

To ensure strong quality of data, the research team administered the initial questionnaire through an intensely focused, in-person, data-gathering effort with participation from a small number of agencies. The team anticipated that the type of data for which it was looking would not be easily accessible and that differences in language and approach from one agency to another would result in incomplete and unreliable data if great care wasn't taken in the collection process. In-person visits, along with preparation beforehand, would allow for the collection of more and higher quality data, which could be expected to form a strong basis for the rest of the research process.

In practice, however, finding and assembling the desired data proved more difficult than anticipated. Many agencies that the researchers thought would participate did not. Other agencies did participate, but the process took much longer than anticipated. At some agencies, especially those on the smaller end of the data set, the data sought by the research team were simply not available. In many cases, the source data were found and, for the first time, the necessary calculations were made to provide the desired data (e.g., combining planned mileage intervals for certain maintenance tasks with number of vehicles, number of miles per vehicle per year, and estimated hours per event to get an annual aggregate number of hours for a task).

Second Round of Data Collection—Revised Questionnaire

The length and complexity of the initial questionnaire created difficulties for many of the transit systems that attempted to complete it, even with substantial assistance from the project team. Often clear answers were not available and had to be inferred in various ways from existing data. Based on this experience, for the second round of data collection, the team developed a revised questionnaire that reflected a simple, straightforward approach to getting the data required. The questionnaire was designed to be completed by a maintenance manager online within an hour.

The research team's goal was to identify 50 additional agencies to participate in the second round of data collection. The team targeted over 200 agencies to achieve the desired participation. The outreach efforts included the Bus Fleet Maintenance listserv originally developed through TRB and now maintained by the Center for Urban Transportation Research (CUTR). The research team also sought assistance from APTA to identify the most appropriate people to contact for participation. The questionnaire was announced to a LinkedIn mass transit group. Finally, there were direct follow-ups with agencies that were approached for the first round of data collection but were unable to participate.

Participating Agency Characteristics

The final set of initial questionnaire participants included 24 agencies. Additionally, three subcontractors with fully separate fleets and staffing completed the survey and can be considered as additional data points. The revised questionnaire was completed by 41 agencies. The full participant list for both rounds of data collection, sorted by fleet size is provided as Table 4.

Table 4. Agencies participating in the data-gathering effort.

Final Participating Agencies	City, State (Province)	Vehicles Maintained	Round 1[a]	Round 2[b]
MTA New York City Transit (NYCT)	New York, NY	4,431	x	
Los Angeles County Metropolitan Transportation Authority (LACMTA)	Los Angeles, CA	2,246	x	
King County Department of Transportation—Metro Transit Division (King County Metro)	Seattle, WA	1,456	x	
Southeastern Pennsylvania Transportation Authority	Philadelphia, PA	1,370		x
Coast Mountain Transit (TransLink) Metro	Vancouver, BC	1,304	x	
Massachusetts Bay Transportation Authority	Boston, MA	1,011		x
City of Edmonton	Edmonton, AB, Canada	941		x
Minneapolis–St. Paul Metro Transit	Minneapolis, MN	877	x	
Pace—Suburban Bus Division (PACE)	Arlington Heights, IL	725	x	
Dallas Area Rapid Transit	Dallas, TX	654		x
Tri-County Metropolitan Transportation District of Oregon (TriMet)	Portland, OR	595	x	
Alameda-Contra Costa Transit District (AC Transit)	Oakland, CA	569	x	
GO Transit—a division of Metrolinx	Toronto, ON, Canada	500		x
Santa Clara Valley Transportation Authority (VTA)	San Jose, CA	426	x	
Orange County Transportation Authority (OCTA)	Orange, CA	416	x	
MV Transit, subcontractor to OCTA	Orange, CA	400	x	
Milwaukee County Transit System (MCTS)	Milwaukee, WI	387	x	
Rhode Island Public Transit Authority (RIPTA)	Providence, RI	379	x	
Brampton Transit	Brampton, ON, Canada	341		x
Charlotte Area Transit	Charlotte, NC	317		x
Broward County Transit	Ft. Lauderdale, FL	311		x
Jacksonville Transportation Authority	Jacksonville, FL	280		x
Capital District Transportation Authority (CDTA)	Albany, NY	272	x	

(continued on next page)

Table 4. (Continued).

Final Participating Agencies	City, State (Province)	Vehicles Maintained	Round 1[a]	Round 2[b]
Grand River Transit	Kitchener, ON, Canada	270		x
City of Tucson (COT) (Veolia Operation)	Tucson, AZ	252	x	
San Mateo County Transit District (SamTrans)	San Carlos, CA	228	x	
Hamilton Street Railway	Hamilton, ON, Canada	226		x
Transit Authority of River City	Louisville, KY	220		x
The Rapid	Grand Rapids, MI	208		x
Greater Dayton Regional Transit	Dayton, OH	199		x
London Transit Commission	London, ON, Canada	193		x
Golden Gate Bridge, Highway and Transportation District (GGBHTD)	San Francisco, CA	188	x	
Clark County Public Transportation Benefit Area Authority (C-Tran)	Vancouver, WA	160	x	
Palm Tran—Palm Beach County	West Palm Beach, FL	156		x
Capital Area Transportation Authority	Lansing, MI	138		x
Lane Transit District	Eugen, OR	137		x
Potomac and Rappahannock Transportation Commission (PRTC)	Woodbridge, VA	135	x	
Chapel Hill Transit	Chapel Hill, NC	123		x
Centre Area Transportation Authority (CATA)	State College, PA	117	x	
City of Regina	Regina, SK, Canada	115		x
Santa Barbara Metropolitan Transit District	Santa Barbara, CA	108		x
Windsor, Ontario, Transit Windsor	Windsor, ON, Canada	104	x	
Whatcom Transportation Authority	Bellingham, WA	94		x
Victor Valley Transit Authority	Hesperia, CA	93		x
City of Tallahassee (StarMetro)	Tallahassee, FL	89	x	
Worcester Regional Transit Authority	Worcester, MA	82		x
Norwalk Transit District	Norwalk, CT	80	x	
Monterey-Salinas Transit (MST)	Monterey, CA	80	x	
City of Thunder Bay	Thunder Bay, ON, Canada	74		x
Guelph Transit	Guleph, ON, Canada	73		x
Rockford Mass Transit District	Rockford, IL	73		x
First Canada	Kelowna, BC, Canada	70		x
Strathcona County Transit	Strathcona County, AB, Canada	65		x
Blacksburg Transit	Blacksburg, VA	64		x
MV Transit, subcontractor to Monterey-Salinas Transit	Monterey, CA	62	x	
MV Transportation, subcontractor to SamTrans	San Francisco, CA	59	x	
Lakeland Area Mass Transit District	Lakeland, FL	59		x
City of St. Albert Transit	St. Albert, AB, Canada	57		x
Rochester Public Transit	Rochester, MN	50		x
Codiac Transpo	Moncton, NB, Canada	40		x
Northern Arizona Intergovernmental Public Transportation Authority (NAIPTA)	Flagstaff, AZ	31		x
River Valley Metro	Bourbonnais, IL	29		x
Fayetteville Area System of Transit	Fayetteville, NC	24		x
Sarnia Transit	Sarnia, ON, Canada	23		x
Reno County Automotive	Hutchinson, KS	18		x
"Upstate" Subcontractor to CDTA for Saratoga Springs	Saratoga Springs, NY	15	x	
Airdrie Transit	Airdrie, AB, Canada	15		x
City of Whitehorse	Whitehorse, YK, Canada	13		x

[a] Initial questionnaire
[b] Revised questionnaire

Table 5. Participating agencies grouped by region.

Region	Round 1[a]	Round 2[b]	Total
California	10	2	12
Northwest	3	2	5
Midwest	3	8	11
Southeast	1	8	9
Southwest	1	1	2
Mid-Atlantic	5	2	7
New England	2	2	4
Canada	2	16	18

[a] Initial questionnaire
[b] Revised questionnaire

Geographic Diversity of Participating Agencies

In identifying the participating agencies, the research team made attempts to group the participants by region and get participation from multiple areas of the United States and Canada, as seen in Table 5.

Efforts were made in the second round of data collection to increase research participation and validation by focusing on agencies in Texas, the Southeast, and the Mountain West.

Size Diversity of Participating Agencies

The participating agencies represented a wide variety of fleet sizes (see Table 6). Because of the effort necessary to respond to the extensive questionnaire, the average size of agencies for the first round of data collection was larger than the overall average agency size nationwide. The focus on relatively larger transit operations meant that all the various potential factors affecting staffing could be better identified. The second round of data collection included a greater percentage of representation from agencies operating 100 vehicles or fewer.

In calculating fleet size, it was important to correctly correlate the fleet with the set of employees maintaining the fleet. Therefore, if a group of employees maintained multiple vehicle modes (e.g., both fixed-route and demand-response vehicles), all relevant modes were included in the fleet size calculation and included in the staffing ratios reported later. If a sub-fleet or mode had an entirely separate staff to maintain it, the fleets and staff were segregated to ensure accurate data and conclusions.

A main lesson learned during the data-gathering process was the great difficulty transit agencies have in tracking and gathering reliable data on maintenance cost, time, and staffing. It was especially difficult to gather information on maintenance times by type of activity. It appears that many agencies do not break down their maintenance hours to show this level of detail. The shorter questionnaire and validation tool developed for the second round of data collection accounted for this difficulty and was a very streamlined survey. The abbreviated survey required less agency time and research to complete. The data gathered lacked the detail originally sought, but added to the aggregate data regarding overall maintenance staffing levels based on more generalized factors such as fleet size and type.

Overall Results

To understand the technician staffing ratios reported, it was necessary to make adjustments to both the numerator of the ratio (number of technicians and/or technician available hours) and the denominator (number of vehicles and/or vehicle miles or vehicle hours) to ensure a consistent representation of the actual staffing situation.

Table 6. Participating agencies grouped by fleet size.

Agency Size	Round 1[a]	Round 2[b]	Total
>1000 Buses	4	2	6
500–999 Buses	3	4	7
250–499 Buses	6	6	12
100–249 Buses	7	10	17
50–99 Buses	5	12	17
<50 Buses	2	7	9

[a] Initial questionnaire
[b] Revised questionnaire

Adjustments to find the number of equivalent technicians were made based on responses in both rounds of data collection about current numbers of employees in various job titles and percentages of each job titles' time assigned to maintenance of the transit fleet. This matrix provided total numbers of employees with various job titles and the percentage of time spent by each group in various roles. This allowed for an adjusted staffing level reflecting only the number of FTEs actually working on maintaining the transit fleet. For example, if an organization listed 50 technicians employed, with 2 of the 50 specifically assigned to maintaining non-transit vehicles and 5% of the overall hours spent on facilities maintenance instead of vehicle maintenance, the adjusted staffing level would be 45.5 FTE technicians (50 technicians – 2 technicians on non-transit vehicles – 5% × 50 technicians on building maintenance = 45.5 technicians). Adjustments could also be made that increased the effective number of technicians, if, for instance, some front line supervisors were in a "working foreperson" type of role, or if "mechanic helpers" were employed. These adjustments relied on estimates from the participating agencies of the percentage of productive time that staff in these positions spent working on transit fleet maintenance tasks.

For technician hours, each agency indicated the number of expected productive hours per employee per year by subtracting holidays, vacation, sick time, lunch, breaks, meetings, and anticipated training from 2,080 hours (52 weeks × 40 hours). In this way, the staffing level and available hours truly represent the amount of labor available for maintaining the specific local fleet. In the Maintenance Staffing Calculator, adjustments will have to be made backwards by an agency—from the calculated maintenance hours needed to the appropriate staff level given the locally expected number of productive hours.

As discussed earlier, under the fleet size of participating agencies, the fleets included were matched to the staff doing the work. If a single staff covers multiple vehicle modes, those modes were considered together as a combined fleet. If there were separate maintenance staffs for each mode, the ratios were considered in isolation with that mode.

The ratios shown in Table 7 are based on reported staffing levels and available productive hours. As a snapshot of existing staffing level and availability, Table 7 shows the ratio of available maintenance hours to fleet size, vehicle miles, or vehicle hours. In addition, the research team analyzed projected maintenance requirements (based on the work order maintenance times reported) and determined whether there were differences between the actual level of staffing and the level of staffing calculated as necessary based on the maintenance requirements.

Although there were 68 participating agencies, not all of them provided sufficient information for all of the potential ratios to be reported, so the actual "n values" are indicated for each ratio shown in Table 7.

The first observation was that for each of the measures there was a large variation in staffing levels among the agencies. By separating out heavy repairs, which are not performed by every agency, the research team hoped to arrive at a narrower range in the numbers of staff maintenance hours required to maintain equivalent fleets for operation. However, even after separating out heavy maintenance, there was still a wide range in agency staffing levels for performing the core fleet maintenance common to every agency. The research team looked at the data from various perspectives to try to understand the driving factors of the staffing ratios. However, from the overall data, it was clear that *there is wide variance in the staff time used per vehicle, mile, and hour for each type of maintenance*, not just in the overall staffing level.

Correlations and Possible Effects of Various Factors

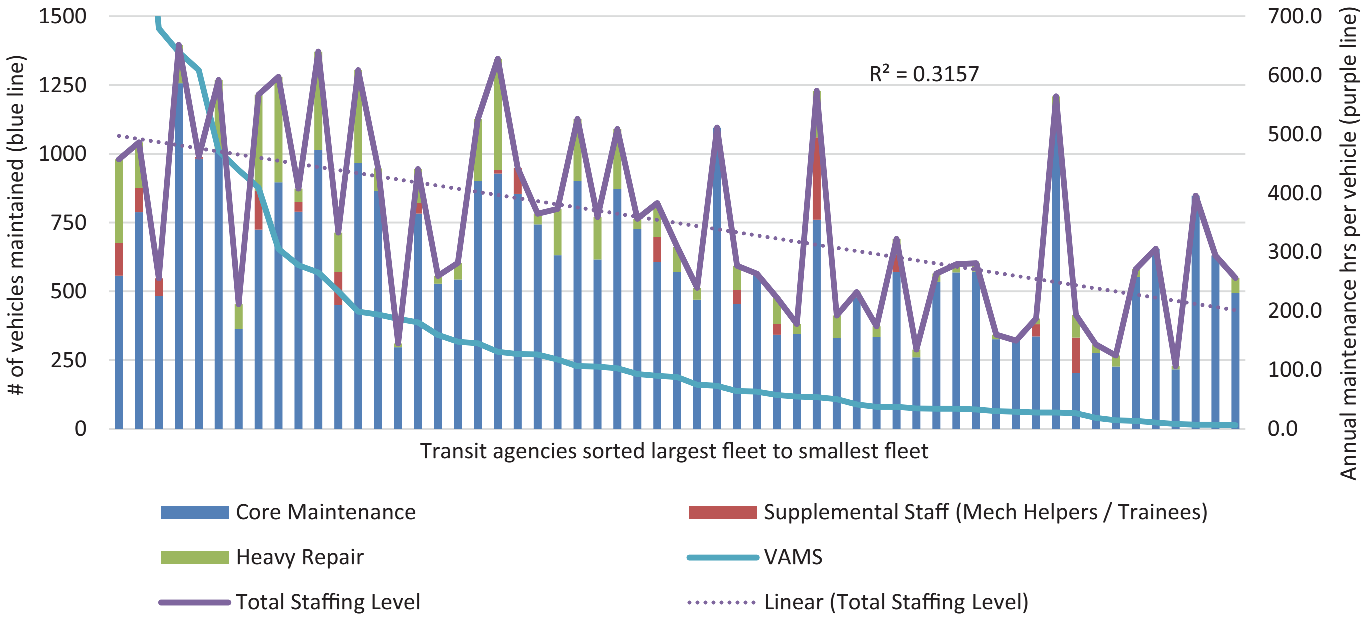
Effect of Fleet Size

In the analysis of NTD data, the research team found that, in general, agencies with larger fleets had more technicians per vehicle and more technician hours per vehicle mile and vehicle

Table 7. Ratio of maintenance technician hours per year per vehicle, per 10,000 vehicle miles and per 1,000 vehicle hours.

Types of maintenance hours	Technician hours per year per vehicle maintained (n=57)		Technician hours per 10,000 vehicle miles (n=51)		Technician hours per 1,000 vehicle hours (n=39)	
	Mean	StDev	Mean	StDev	Mean	StDev
Core maintenance	290.7	121.2	84.1	34.8	116.0	45.9
Adjustment for in-house heavy repair	46.9	51.5	15.0	14.5	16.7	17.4
Mechanic helpers or apprentices	11.5	24.8	3.7	8.5	2.5	6.2
Total maintenance hours	**349.1**	**155.7***	**102.8**	**46.4***	**135.2**	**54.0***

* Standard deviations of subsets don't necessarily sum to the standard deviation of the whole group.

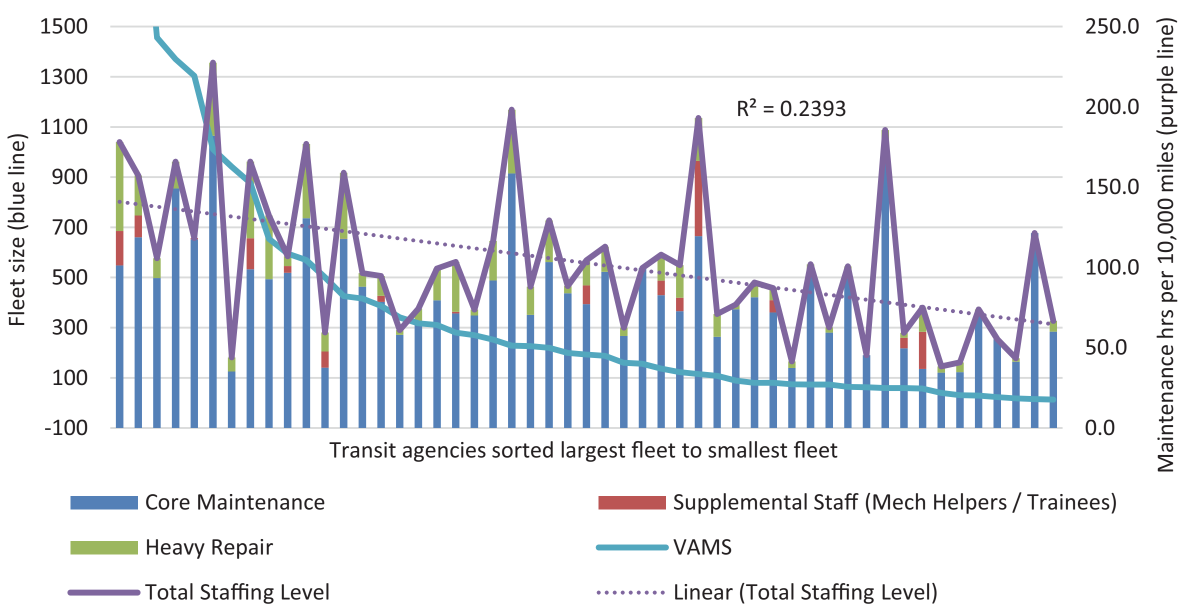


*Fleet size for largest (4,431) and 2nd largest fleets (2,246) are above the max of the left-hand axis scale.

Figure 19. Annual technician hours per vehicle maintained, sorted by fleet size.*

hour. Looking at the data gathered across both rounds of data collection, the research team found that there is indeed a correlation between fleet size and hours of maintenance per vehicle ($R^2 = 0.316$), but a somewhat lower correlation between fleet size and hours of maintenance per 10,000 vehicle miles ($R^2 = 0.2393$). Despite the existence of the correlation, there is still a large variation in technician hours per vehicle being maintained between agencies regardless of fleet size (see Figures 19 and 20).

The charts shown in Figures 19 and 20 depict a general downward trend in staffing ratio as fleet size decreases. Some of the reasons for this trend are that larger agencies can more often complete heavy repairs and overhauls with in-house staff, that the fleet is composed of more complicated vehicles (e.g., hybrid transmissions and/or articulated buses), that more funding is available for staffing, that these factors overcome the economies of scale that might be expected in a large operation, or that there is more freedom to maintain via labor costs than



*Fleet size for largest (4,431) and 2nd largest fleets (2,246) are above the max of the left-hand axis scale.

Figure 20. Technician hours per 10,000 vehicle miles, sorted by fleet size.*

via parts costs. It is highly likely that a different subset of these factors and other unique factors are affecting each individual agency's staffing level.

Despite the overall trend shown in Figures 19 and 20, at all fleet size levels, there are individual agencies significantly above or below the trend line. It is also apparent that the insourcing of heavy repair tasks (depicted by the green bar in Figures 19 and 20) does not entirely explain the larger average staffing ratios at larger agencies. Figures 21 through 23 show the total maintenance hours broken down into core maintenance, supplemental staff (mechanics' helpers and apprentices/trainees), and hours for heavy maintenance and repair.

Figure 21 indicates that the average of core maintenance hours per vehicle tends to be lower at the smaller agencies.

The breakdown of maintenance hours (Figures 21, 22, and 23) shows that higher staffing levels at larger agencies are only partially due to heavy maintenance and overhaul. Even for the core maintenance tasks, larger agencies show more maintenance hours per year per vehicle. This may be due to other characteristics of the fleet, maintenance and labor practices, availability of funding, or other unknown factors. A dynamic analysis of all these factors would be needed to make conclusive determinations.

Figures 24 and 25 show all of the types of maintenance by fleet size together.

Figures 24 and 25, like Figures 21 and 23, show that although some of the overall variation in number of maintenance technician hours between larger and smaller agencies is due to the larger investment in heavy maintenance at large agencies, variation exists even among the core maintenance tasks. The sections that follow discuss some additional possible sources of this variation.

Effect of Fleet Characteristics

In addition to fleet size, the correlation of staffing level to various fleet characteristics was also analyzed. There were three elements of fleet composition where a correlation with staffing level was found: (1) the percentage of a fleet that is made up of articulated vehicles, (2) the percentage of a fleet that is made up of cut-away vehicles, and (3) the fleet spare ratio.

The percentage of vehicles that are non-standard (articulated or cut-away) has a slight correlation with staffing levels, but it is not clear if this is an actual driver of staffing level. As the percentage of articulated vehicles in a fleet increases, the hours of maintenance per vehicle for the fleet also increases ($R^2 = 0.1075$) (see Figure 26). (Note that this correlation decreased significantly in the second round of data collection compared to what was found in the first round—the previous R^2 value was 0.27.) As the percentage of cut-away vehicles

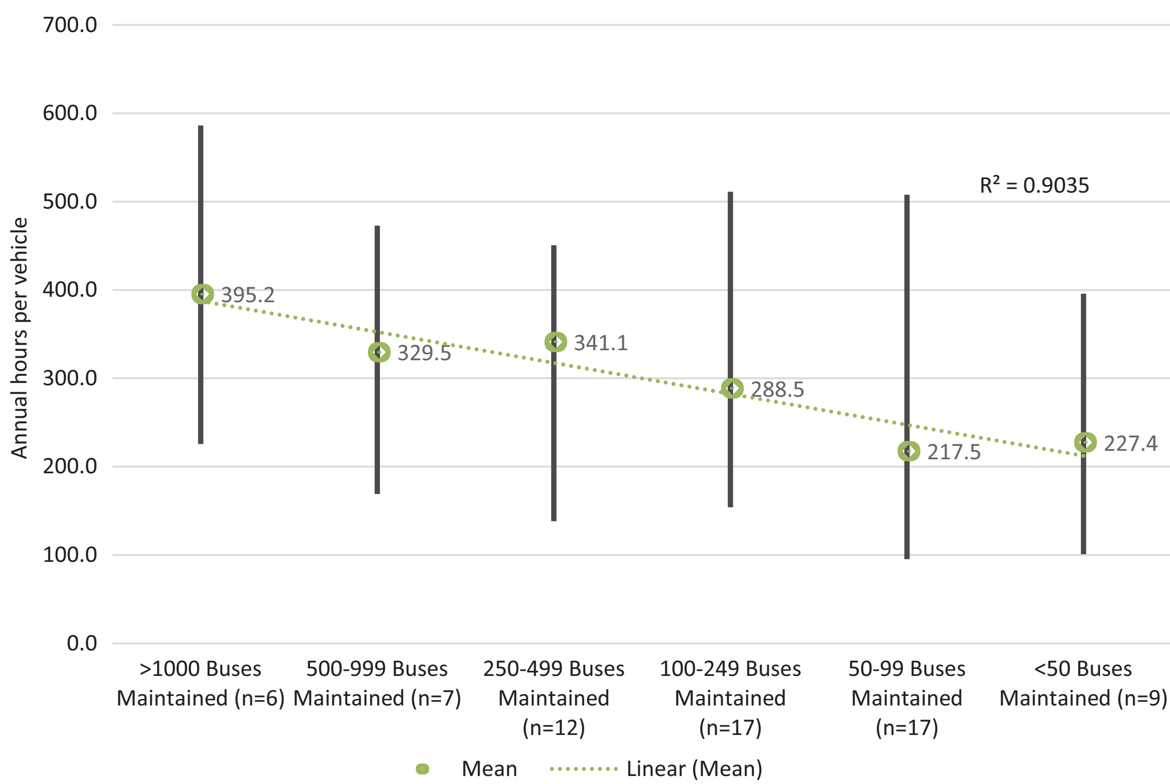


Figure 21. Core maintenance by fleet size.

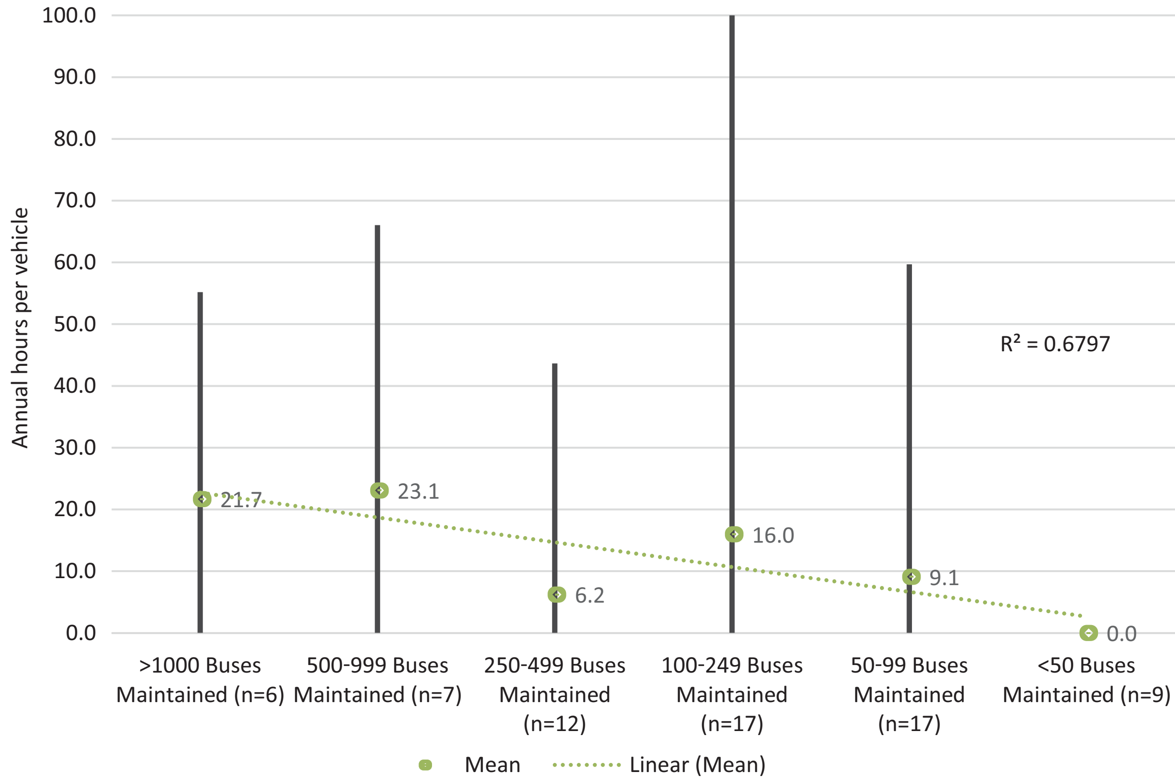


Figure 22. Supplemental staff hours by fleet size.

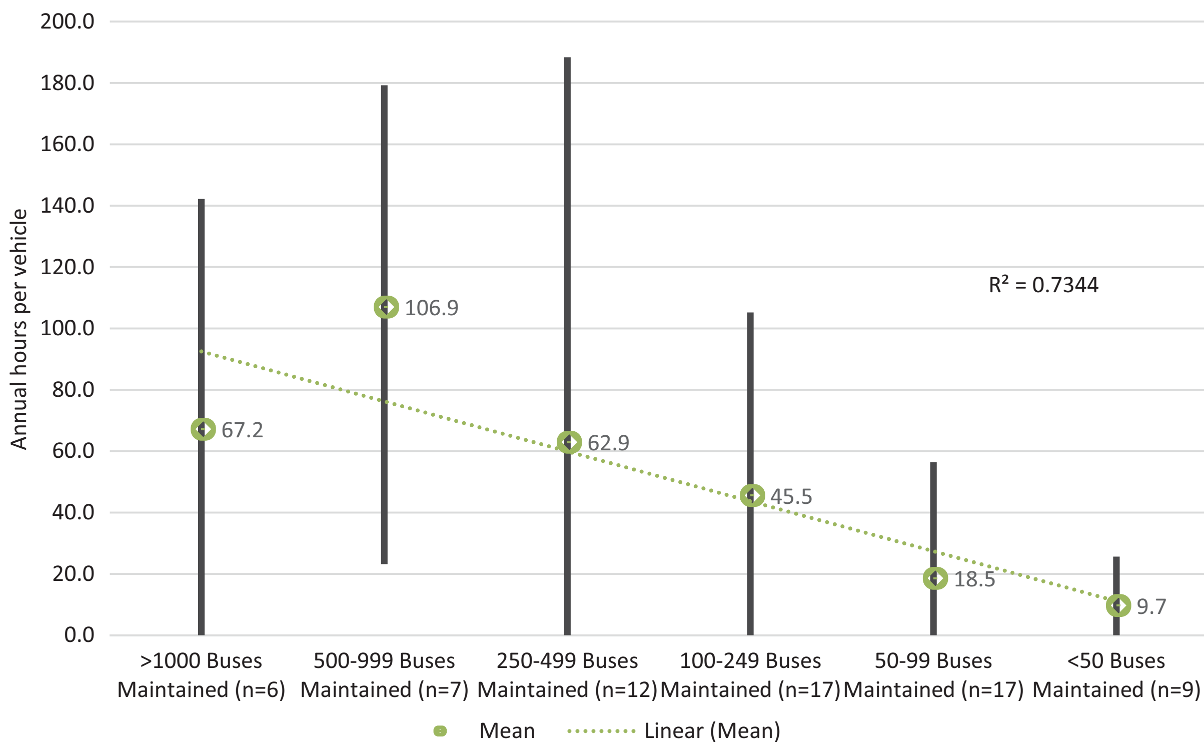


Figure 23. Heavy maintenance hours by fleet size.

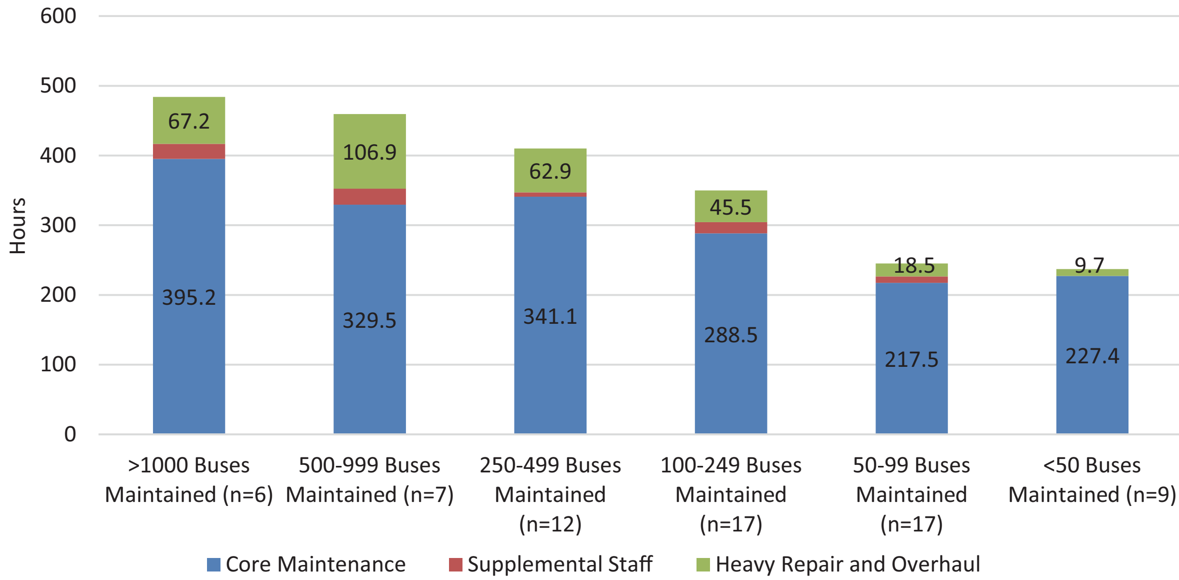


Figure 24. Annual maintenance technician hours per vehicle maintained.

in a fleet increases, the hours of maintenance per vehicle will tend to decrease ($R^2 = 0.1912$) (see Figure 27). This may partially explain why agencies with smaller fleets have smaller numbers of technician hours per vehicle: the smaller agencies tend to have smaller vehicles (few or no articulated vehicles and a number of cut-away vehicles) and these may be less complicated to maintain.

In the first round of data collection, there was a small correlation between spare ratio and staffing level ($R^2 = 0.1096$), but this virtually disappeared with the additional data collection ($R^2 = 0.0178$). During the analysis, the research team never saw anything like the large correlation for spare ratio present in the NTD data. It could be that the definition of VAMS is different across agencies, and spare ratios are not actually as high as they appear.

The research team also analyzed the relationship for fleet miles per hour (as a measure of a typical duty cycle) and average vehicle age, but virtually no correlation to staffing levels

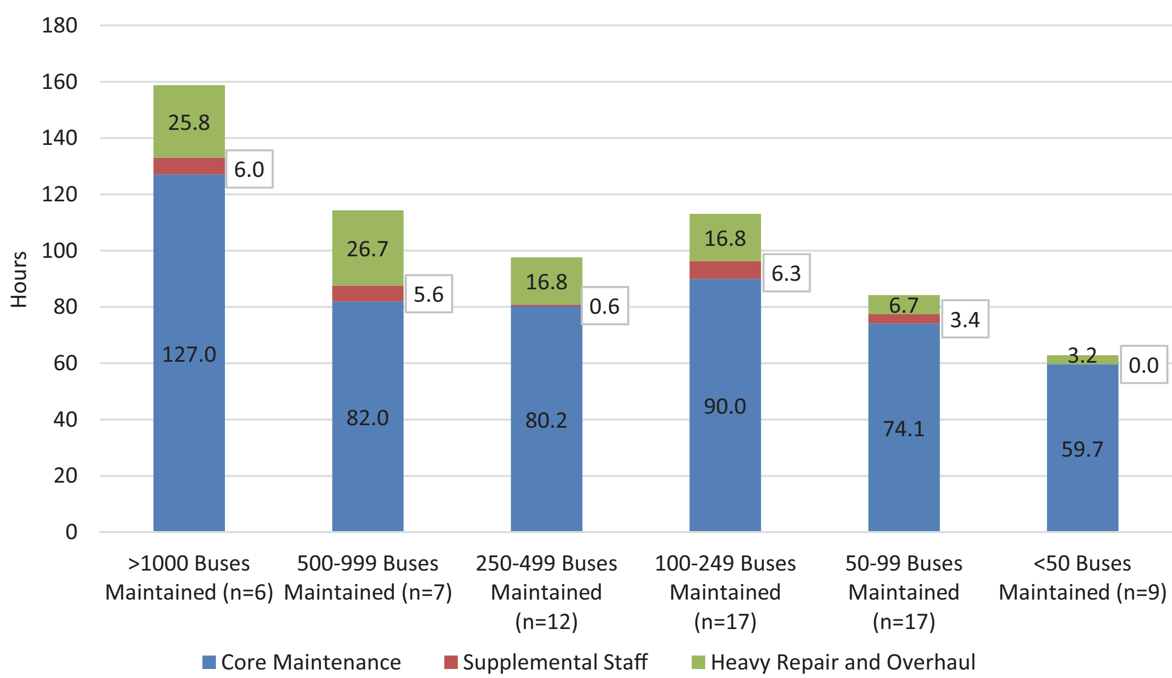


Figure 25. Maintenance technician hours per 10,000 vehicle miles.

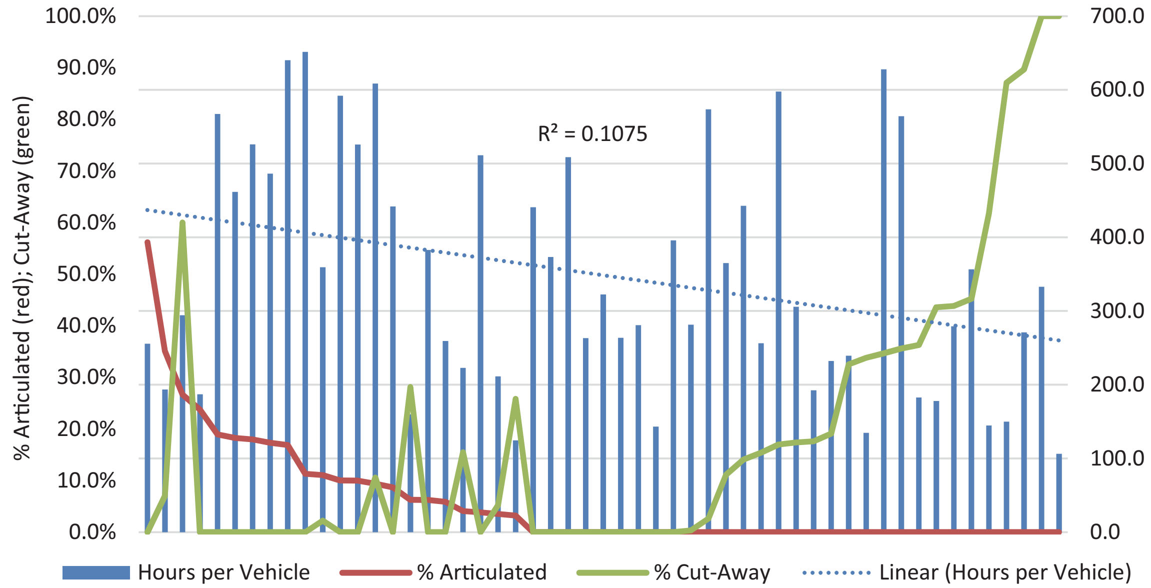


Figure 26. Annual maintenance hours per vehicle maintained, sorted by percentage of articulated vehicles in fleet.

was identified for these variables ($R^2 = 0.023$ for duty cycle, $R^2 = 0.014$ for fleet age).

Effect of Maintenance Practices

There was almost no correlation observed between the percentage of total maintenance time spent on PMI and staffing level ($R^2 = 0.0214$) (see Figure 28). Also, there was almost no correlation between time spent on all scheduled maintenance and staffing level ($R^2 = 0.0289$) (see Figure 29). (Note that these data were only gathered in the first round of analysis. Because of the low correlation found, these data were not gathered in the second round.) The project team believes that despite early efforts to define terms carefully, there may have been some confusion about what to include in PMI or how to distinguish between scheduled and unscheduled maintenance. Some agencies may have reported just the time spent inspecting the vehicle, others

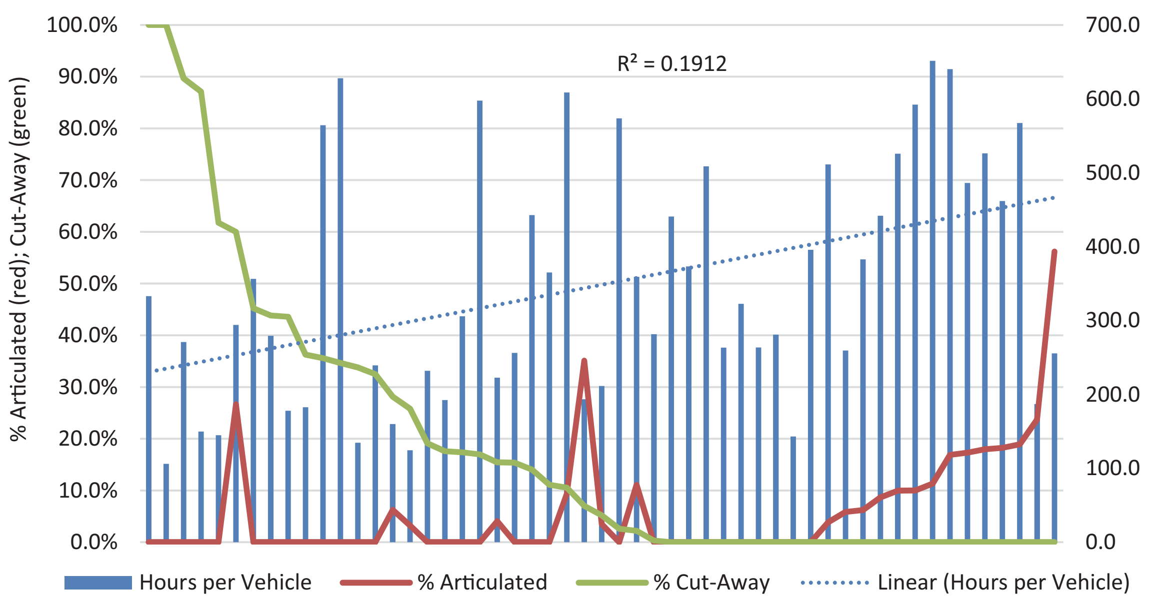


Figure 27. Annual maintenance hours per vehicle maintained, sorted by percentage of cut-away vehicles in fleet.

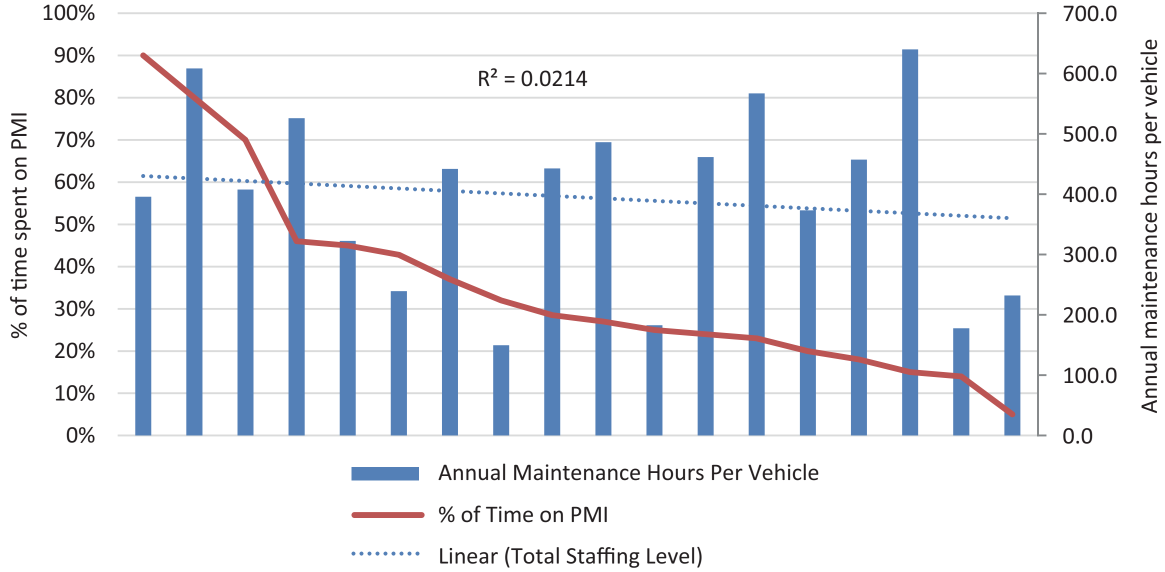


Figure 28. Annual maintenance hours per vehicle maintained, sorted by percentage of time spent on PMI.

may have included all of the maintenance work orders generated from those inspections, and yet another group may have included almost all maintenance except repairs from an in-service breakdown.

Effect of Investment in Training

The agencies that calculated the amount of training per technician each year reported a wide variation in training investment. One agency reported that technicians spent 200 hours per year in training; other agencies reported that technicians spent as few as 4 to 8 hours per year in training. Nonetheless, there was no correlation between the amount of training hours and the annual maintenance hours per vehicle (see Figure 30). It may be the case that agencies with a lower training investment are able to hire already skilled workers. It is difficult to isolate the specific effects of training on staffing levels without looking very carefully at starting skill levels of workers, training topics, and subsequent performance in specific areas.

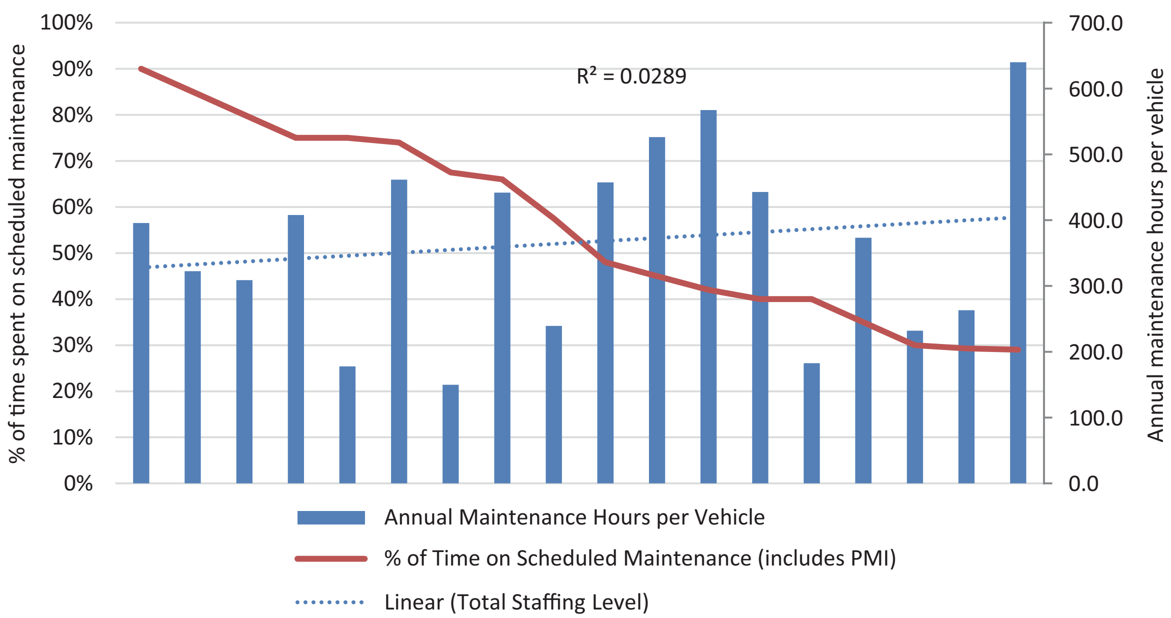


Figure 29. Annual maintenance hours per vehicle, sorted by percentage of time spent on scheduled maintenance.

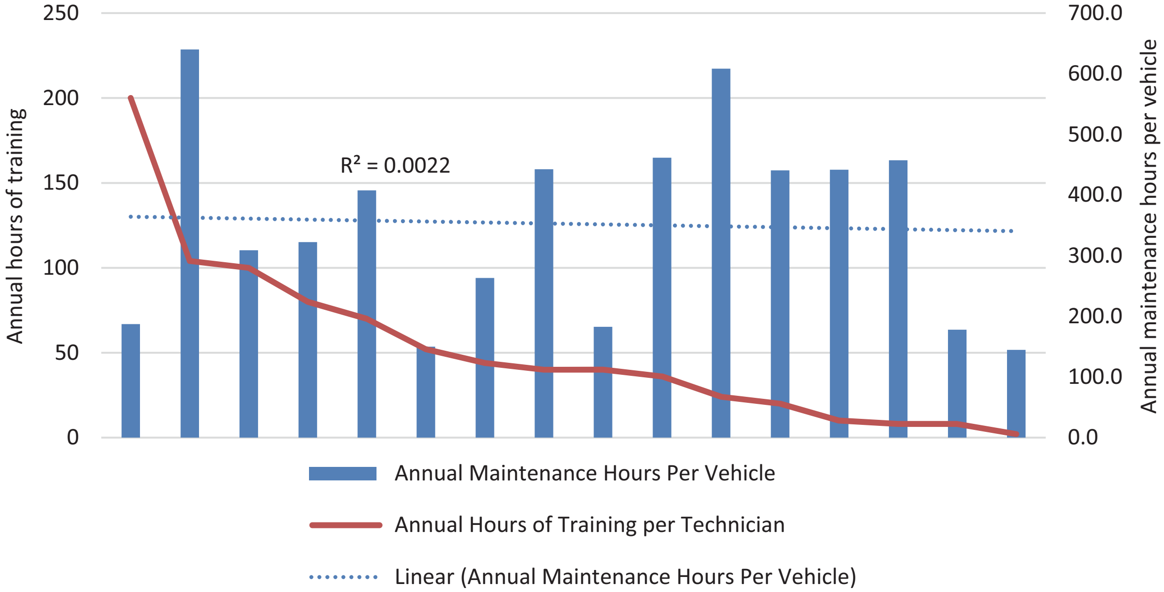


Figure 30. Annual maintenance hours per vehicle, sorted by annual training hours per technician.

Supply Model versus Demand Model

The research reported herein has so far been focused on actual staffing levels. The agencies also reported demanded maintenance, but this did not always correlate with reported staffing levels. It may be the case that some work order tracking systems are not capturing the full amount of maintenance hours. Ideally, agencies using the Maintenance Staffing Calculator developed in this research will calculate a total number of maintenance hours needed; the User Guide will help them identify what factors are driving them above or below that projected number.

CHAPTER 3

Training Practices, Skill Gap Analysis, and Connection to Staffing Levels

The research team explored correlations among reported technician skill levels, training time and resources, and staffing levels using a Skilldex survey.

Three agencies participated extensively in the Skilldex survey: New York City Transit, Monterey-Salinas Transit (along with its subcontractor), and King County Metro Transit. Two additional agencies had very minimal participation. There were also two agencies that participated in the first round of data collection that had separately completed Skilldex surveys with the researchers prior to the beginning of the TCRP E-10 project, and these data were included in the analysis.

There was no correlation identified between the number of training hours per technician per year and the number of maintenance hours per vehicle per year. Likewise, the data showed no significant correlation between training investment and reported skill levels. Further, reported skill levels did not correlate significantly with annual maintenance hours. The research team believes that there are again too many underlying factors to isolate the effects of training in a project of this scope. These factors include the starting skill level of the local workforce, the ability of larger agencies to have their technicians specialize in certain areas or job assignments, and a mixture of the quality of training.

CHAPTER 4

Maintenance Staffing Calculator and User Guide

A simple calculator (the Maintenance Staffing Calculator) was developed for agencies to input basic information on current fleet and staff and receive a comparison of their various staffing ratios to a peer group of agencies. The Maintenance Staffing Calculator was offered for validation to the participants in the initial and revised questionnaires.

Through analysis and detailed discussions with agencies and the TCRP Project E-10 panel on how to make the Maintenance Staffing Calculator useful to all types of agencies, desired elements of the Maintenance Staffing Calculator were identified. These elements included the following:

- A breakdown of staff by location and/or sub-fleet
- Adjustment of current staff to FTEs and available productive hours using information on current technician staffing; other employees contributing to maintenance; and breaks, vacations, and shifts
- Calculations of preventive maintenance, core maintenance, and unscheduled maintenance task hours required by sub-fleet
- Calculations of heavy maintenance and repair hours required
- The ability to model changes to fleet composition or usage
- The ability to model changes to maintenance times or intervals
- A way to account for required overtime
- A dashboard to compare current staff, calculate required staff, and revise staff based on changes modeled
- A comparison of results to a group of peer agencies

The resulting Maintenance Staffing Calculator and User Guide include all of these elements. The Maintenance Staffing Calculator is very flexible and can be used by all types of agencies for very detailed analyses or quick snapshots. The Maintenance Staffing Calculator and User Guide are available on the TRB website by searching on *TCRP Report 184*.

The benchmarks for each peer group of agencies included in the Maintenance Staffing Calculator are based on all 68 survey participants from both rounds of data collection. As additional data were gathered, the reliability of the data increased and the range of vehicles for each peer group was tightened.

The peer group benchmarks used for the Maintenance Staffing Calculator are shown in Table 8.

Table 8. Peer group benchmarks used for the Maintenance Staffing Calculator.

	Number of Vehicles Maintained											
	>1000 (n = 6)		500–999 (n = 7)		250–499 (n = 12)		100–249 (n = 17)		50–99 (n = 17)		<50 (n = 9)	
	Avg	Std Dev	Avg	Std Dev	Avg	Std Dev	Avg	Std Dev	Avg	Std Dev	Avg	Std Dev
Vehicles maintained per technician	3.5	1.3	4.4	2.0	4.9	3.0	5.7	1.9	7.3	2.7	8.1	4.4
Vehicle miles per technician	102,227	24,682	182,505	107,668	176,163	54,629	177,628	55,506	213,378	79,957	278,509	89,792
Vehicle hours per technician	10,301	1,441	10,842	4,159	12,264	3,947	13,187	2,914	14,732	5,223	16,975	5,540
FTE technicians per vehicle	0.31	0.09	0.27	0.11	0.25	0.09	0.20	0.08	0.16	0.06	0.15	0.1
FTE technicians per 10,000 vehicle miles	0.10	0.02	0.07	0.03	0.06	0.02	0.06	0.02	0.05	0.02	0.04	0.0
FTE technicians per 1,000 vehicle hours	0.10	0.01	0.10	0.03	0.09	0.03	0.08	0.02	0.08	0.04	0.06	0.0
Annual total maintenance hours per vehicle	484.0	136.5	459.5	169.4	410.1	147.0	337.2	117.9	247.0	116.7	237.1	102.3
Annual total maintenance hours per 10,000 vehicle miles	158.8	43.8	114.3	54.6	97.6	28.8	108.3	33.7	84.5	39.2	62.9	29.1
Annual total maintenance hours per 1,000 vehicle hours	150.1	21.4	166.3	59.8	142.3	43.8	142.7	38.5	127.3	77.6	102.3	41.0
Annual miles per vehicle	30,847	6,819	40,736	9,545	45,121	8,679	33,462	9,639	29,362	6,770	36,056	10,100
Annual hours per vehicle	3,151.9	324.4	2,404.4	614.4	2,976.0	574.4	2,271.7	731.3	2,003.4	405.4	2,379.1	820.2
Average miles per hour in operation	10.2	2.4	17.9	5.7	14.6	3.5	14.6	2.9	14.0	2.8	15.8	3.5
Fleet average age	8.4	0.7	9.1	3.2	7.0	1.8	8.7	2.3	7.6	2.6	8.3	1.0

CHAPTER 5

Implementation Plan and Future Research

The Maintenance Staffing Calculator was developed with the intent that it would be utilized across the transit industry and continuously updated to sustain usefulness and relevance. Multiple venues are being utilized to publicize the Maintenance Staffing Calculator. The Maintenance Staffing Calculator could possibly reside with the APTA Bus Maintenance Training Committee. The committee would provide assistance to agencies using the Maintenance Staffing Calculator, be a clearing house for data collected, and maintain and update the Maintenance Staffing Calculator. The benchmarks could be continually updated and expanded as participating agencies share their results, giving agencies a better sense of how they compare to their peer group.

The research team suggests that future research on this topic could include research into best practices for maintenance data collection and determining trade-offs between staffing levels and parts costs. During the project, several agencies also expressed interest in a rail car maintenance version of the Maintenance Staffing Calculator, which could be developed using the Maintenance Staffing Calculator as the platform, with modifications specific to rail car maintenance.

The ultimate conclusion of the research is that bus maintenance staffing levels are subject to a substantial number of variables based on many distinct local conditions. There is no clear outside formula that can tell an agency what its staffing level ought to be, but the Maintenance Staffing Calculator and User Guide can help an agency to more clearly see what drives its needs and how it can plan and respond given its unique fleet maintenance requirements.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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