ABSTRACT

In 2009, transit agencies in the United States spent nearly 60% of their bus transit capital funds on their revenue vehicles. Using 25 years of data from the National Transit Database (NTD), this paper examines the national trends of seven major characteristics associated specifically with bus revenue vehicles. These trends can provide important information on where the market might be heading and aid in the planning decision on transit investments. The characteristics examined include number of vehicles, spare ratio, average age, average capacity, ADA accessibility, vehicle reliability, and vehicle operations and maintenance expenses. Some findings from the trend data include: (1) a steady increase in the privatization of bus services; (2) the average spare ratios have consistently exceeded the maximum of 20%, as suggested by the Federal Transit Administration for systems operating with more than 50 vehicles; (3) vehicles operated by contractors tended to be significantly newer than those operated directly by transit agencies, although the gap has narrowed in recent years; (4) vehicles operated directly by transit agencies tended to have higher seating and standing capacities than those operated by contractors; (5) there was a tendency among transit agencies to trade seats for more standing room; (6) by 2006, nearly all bus vehicles were ADA-compliant, and increasingly vehicles with lifts were converted to vehicles with ramps/low-floor; (7) reliability of vehicles in terms of number mechanical failures per million revenue vehicle miles has significantly improved over the years; and (8) contractors spent less on average than transit agencies in operating and maintaining their vehicles.

Keywords: Bus Vehicle Characteristics, Transit Planning, Trend Analysis, National Transit Database (NTD)
INTRODUCTION

Bus transit systems have continued to be the dominant mode of public transportation in the United States (U.S.). Figure 1 shows that in 2009, urban bus transit systems in the U.S. served a total of 5.36 billion unlinked passenger trips. This number represents an increase from the 4.51 billion trips in 1996, but still slightly below the 5.41 billion trips achieved in 1985. Figure 1 also shows a steady decline in transit market share for buses over the years, decreasing from 64.8% in 1985 to 52.9% in 2009. During the same period, the market share for heavy rail systems increased from 27.4% to 34.4% while for light rail systems, the number increased from 1.6% to 4.6%, suggesting a transit mode shift from bus to rail systems. Other transit modes, including commuter rail, automated guideway, monorail, demand response, jitney, etc., collectively increased only slightly, from 6.2% to 8.1% over the same period. While the market share by bus transit systems is likely to continue its downward swing, the recent trend indicates that the actual number of bus transit trips is more likely to continue to increase.

![Figure 1 Total and Percent Share of Unlinked Bus Passenger Trips](image)

For most bus transit agencies, investments in revenue vehicles usually represent a major use of their capital funds. Figure 2 shows that in 2009, capital expenses for the acquisition and rehabilitation of revenue vehicles accounted for 58.9% of the total capital funds of bus transit agencies, compared to 14.0% for building maintenance, 8.2% for passenger stations, 5.9% for information and communication systems, and 13.1% for miscellaneous other capital investments. This paper will examine the national trends of seven major characteristics associated specifically with bus transit vehicles. These trends provide important information on where the market might be heading and can aid in the planning of transit investments. The characteristics examined include number of vehicles, vehicle spare ratio, average vehicle age, average vehicle capacity, ADA accessibility, vehicle reliability, and vehicle operations and maintenance expenses.
DATA SOURCES

The data used in this study came from the National Transit Database (NTD). They are, thus, limited to only those transit service providers that reported to NTD under the Urbanized Area Formula Program. NTD is a uniform data set collected as part of the requirements for transit agencies to receive federal grant funds. First collected in 1978 and distributed by the then Urban Mass Transportation Administration (UMTA), NTD has become the sole source of standardized and comprehensive data for use by all constituencies of the U.S. transit industry (Lyons and Fleischman 1992). NTD includes data on transit organization characteristics, vehicle fleet characteristics, revenues and subsidies, operating and maintenance costs, vehicle fleet reliability and inventory, services consumed and supplied, and safety and security. These data not only provide direct information on the urban transit systems in the U.S., but can also be used to derive transit performance measures.

The latest NTD data are reported on a set of 19 standard forms covering seven different reporting areas. Among these forms, some are reported for the entire transit agencies, while others for individual transit modes and/or service types. A service type can be either directly operated (DO), if the service is provided in-house, or purchased transportation (PT), if the service is contracted to an outside service provider. When a service is contracted out, the NTD data may be reported either by the transit agency or by the subcontractor.

While the majority of the NTD data collected are made available to the public through the Federal Transit Administration (FTA), access to these data has not been easy. One major reason is because NTD data have been collected and distributed annually on separate files. As a result, trend data must be manually extracted from individual files and then combined for analysis. The process is both time consuming and often error-prone, especially for the novice users (Gan and Gui 2009).
To facilitate the access and analysis of multiple years of NTD data, a web-based system called the Integrated National Transit Database Analysis System (INTDAS) was developed by the authors (INTDAS Homepage). The system integrates multiple years of NTD data in a single standardized database and provides a user-friendly interface for quick data retrieval and analysis. Based on the 1985-2009 NTD data extracted from the system, the following sections examine the national trends from 1985 to 2009 for each of the aforementioned seven characteristics associated with bus transit vehicles.

**AVERAGE FLEET SIZE**

NTD includes two variables for the reporting of fleet size, i.e., vehicles available for maximum service and vehicles operated in maximum service. Vehicles available for maximum service include the number of vehicles available for use by a transit agency to meet the annual maximum service requirement. Specifically, they include spare vehicles, out-of-service vehicles, and vehicles in or awaiting maintenance, but exclude vehicles awaiting sale, and emergency and contingency vehicles. Vehicles operated in maximum service, on the other hand, include the number of revenue vehicles operated to meet the annual maximum service requirement, i.e., the revenue vehicle count during the peak hours of the peak days/weeks of the peak season (NTD 2009).

Figure 3 gives the nationwide totals from 1985 to 2009 for bus vehicles available and operated for maximum service. The figure shows that, from 1985 to 1996, the number of vehicles nationwide remained relatively stable. However, starting from 1996 through 2009, the number of vehicles increased steadily at an average rate of about 1,000 additional buses a year, or about 1.4% per year, compared to the 0.5% of total increase over the entire period from 1985 to 1996. The increase in bus vehicles also coincides with the increase in the number of bus passenger trips since 1996.
In terms of vehicles per transit system, Figure 4 shows that the average number of buses operated directly by transit agencies has continued to decrease between 1985 and 2009, while the average rolling stock of contracted service providers has increased. Figure 5 plots the contracted vehicles as a percent of the total vehicles. The figure clearly shows an increasing trend in privatizing bus services, from 3.7% in 1985 to a high of 16.5% in 2009.
SPARE RATIOS

Spare vehicles are usually maintained as backups for interruptions. Two formulas have been used to calculate spare ratio (SR):

\[ SR_1 = \frac{N_a - N_o}{N_o} \times 100 \]  \hspace{1cm} (1)

\[ SR_2 = \frac{N_a - N_o}{N_a} \times 100 \]  \hspace{1cm} (2)

where \( N_a \) is the number of vehicles available for maximum service, and \( N_o \) is the number of vehicles operated for maximum service.

The main difference between the two formulas is their divisors. Formula (1) normalizes the spare vehicles by the number of operated vehicles while Formula (2) does so by the number of available vehicles. Since by definition \( N_a \) is greater than \( N_o \), the range for \( SR_1 \) is \([0, \infty]\) and the range for \( SR_2 \) is \([0, 1]\). It can easily be shown that \( SR_1 \) is always greater than \( SR_2 \), with the only exception being when both spare ratios are zero. It can also be shown that the difference between the two formulas tends to increase with the increase in spare vehicles. For example, if one out of ten vehicles is used as a spare vehicle, \( SR_1 = 11\% \) and \( SR_2 = 10\% \), with a difference of 1%. If four out of ten vehicles are used as spare vehicles, \( SR_1 = 150\% \) and \( SR_2 = 60\% \), with a difference of 90%. It is thus highly critical that one finds out the formula(s) used when comparing spare ratios from different sources.

Figure 6 shows the average spare ratios based on both formulas for both directly operated (DO) and purchased (PT) service types. The figure shows that the spare ratios calculated using the two different formulas, even at the aggregated national level, differ by as much as 9%. The same figure also shows no significant difference in spare ratio between the DO and PT services, especially for those after 1990.

Although the \([0, 1]\) range of Formula (2) is easier to understand and compare, Formula (1) with an open range of \([0, \infty]\) is the formula officially adopted by the FTA (2008). The FTA further suggests that the spare ratio for agencies operating 50 or more revenue vehicles should not exceed 20%. However, using Formula (1), Figure 7 shows that, nationwide, the spare ratio had consistently exceeded 20% for systems operating with more than 50 vehicles. For smaller systems with less than 50 vehicles, the spare ratios are significantly higher.
Figure 6. Spare Ratios by Different Service Types and Formulas

Figure 7. Spare Ratios by System Fleet Size
**AVERAGE AGE OF BUS VEHICLES**

Average fleet age is an important measure as older buses tend to require more maintenance and result in poorer condition ratings. A study by Karlaftis (2010) shows that one additional year of age contributes to a 30% increase in expected maintenance time. As part of its Revenue Vehicle Inventory form, NTD provides the following two variables that can be used to calculate the average age of vehicle fleets: number of active vehicles and years of manufacture (NTD 2009).

Figure 8 shows that overall, the average fleet age during the period from 1991 through 2009 ranged from 7.0 and 8.8 years and the numbers exhibited an interesting cyclic pattern. The same figure also shows that contracted bus vehicles tend to be newer. However, the gap has narrowed from a high of about two years in 1992, to less than one year in recent years. The shapes of the curves show that the narrowing of the gap was not due to the lowering of the average fleet age of contracted vehicles, but to an increase in the number of new buses purchased by transit agencies. Note that the data before 1991 are not plotted because the vehicle inventory data in NTD prior to 1991 did not identify the specific mode that the vehicles were used for, making it impossible to determine if a vehicle was used for fixed-route bus service or some other services such as demand response.

![Figure 8 Average Ages of Fleets](image)

**AVERAGE PASSENGER CAPACITIES**

Vehicle seating capacity and standing capacity were added to the NTD in 1991. The seating capacity is the actual number of seats on-board the vehicle and is usually cited in the specifications used to manufacture the vehicle. Standing capacity, on the other hand, is the number of standees allowed by transit agency policy. Zero is reported if local policy prohibits
standing. In the absence of local policy on the maximum number of standees, the manufacturer-rated standing capacity is reported (NTD 2009).

Figure 9 plots the seating, standing, and total capacities for both the DO and PT service types. The figure clearly shows that vehicles operated directly by transit agencies maintained higher seating and standing capacities than those provided by outside contractors.

The American Public Transit Association (APTA) suggests for procurement purposes a minimum seating capacity of 43 for a 40-foot bus (APTA 1997). Figure 9 shows that, for directly operated vehicles, this suggested minimum was met in the early 1990’s. However, the average seating capacity has since fallen to around 40. Figure 9 also shows a tendency to trade seating for more standing room in directly operated vehicles. This is evidenced from the decreasing seating capacity and increasing standing capacity over the years. One explanation for this compromise could be due to the enactment of the Americans with Disabilities Act (ADA) in 1990, which required vehicles to provide for wheelchairs access, thus reducing the number of seats.

Reporting of vehicle length was added to NTD in 2002. Consistent with the lower capacity of contracted vehicles, Figure 10 shows that the average vehicle lengths have remained steady over the years, and that contracted vehicles have consistently been about three feet shorter than those of the directly operated vehicles, which averaged slightly below 40 feet.

![Figure 9 Average Passenger Capacities by Service Types](image-url)
ADA ACCESSIBILITY

The status of ADA accessibility of transit vehicles was first reported in the NTD in 1992. From 1992 to 2001, agencies were required to report the number of ADA-accessible vehicles. Additional details were added in 2002 and agencies were required to report the number of vehicles equipped with lifts and the number of vehicles equipped with ramps/low floor. Lift-equipped vehicles use wheelchair lifts. Low floor vehicles do not have stairs inside the front or rear doors, but are usually equipped with a front-door accessible ramp and a kneeling feature that allows easier access for persons with mobility aids, such as those who have difficulty climbing steps or who may use a wheelchair (NTD 2009). A vehicle is considered ADA-accessible if it is equipped with a lift or with ramps/low floor.

Figure 11 plots the percentages of ADA-accessible bus vehicles for both the DO and PT services. The figure shows that when the data were first collected in 1992, the percentages of vehicles that meet the ADA requirements were 42% and 35% for DO and PT, respectively. Overall, there was no significant difference between DO and PT services. By 2006, nearly all of the vehicles were considered ADA-accessible, with a small number of about 1% remaining non-compliant. Figure 11 also plots the percentages of vehicles with lifts and the percentages of buses with ramps/low floor for the period from 2002 to 2009. The figure clearly shows a trend to convert vehicles with lifts to vehicles with ramps/low-floor. It can also be seen that, compared to directly operated vehicles, contracted vehicles were more likely to be equipped with lifts than with ramps/low floor.
VEHICLE RELIABILITY

NTD includes two variables that can be used to assess the mechanical reliability of revenue vehicles. The first is the number of major mechanical system failures. These include the failure of the mechanical components of major systems that prevent the specific revenue vehicle from completing a scheduled revenue trip, or from starting the next scheduled revenue trip, because actual movement is limited or because of safety concerns. The second variable reports some other mechanical element of the revenue vehicle that, because of local agency policy, prevents the revenue vehicle from completing a scheduled revenue trip or from starting the next scheduled revenue trip, even though the vehicle is physically able to continue in revenue service. The third variable is simply the sum of the first two variables (NTD 2009).

Figure 12 plots the average total number of mechanical failures per million revenue vehicle miles (RVM) as a measure of vehicle reliability. Data for the first two variables are not plotted in this figure to avoid skewed totals because some agencies reported only the total mechanical failures. It can be seen that vehicle reliability has improved significantly over the years. Specifically, from 1985 to 2004, the vehicles as a whole experienced a remarkable reduction of about 200% in the number of mechanical failures per million RVM, before it started to taper off at about 210 mechanical failures per million RVM. It is interesting to note that the improvements did not occur in a continuous manner, but with intermittent periods of improvement and stagnation. Figure 13 shows that the period of improvement in vehicle reliability occurred despite an
increase in vehicle usage, as measured by the average revenue vehicle miles served per operated vehicle.

![Figure 12 Average Number of Mechanical Failures per Million Revenue Miles](image1)

**Figure 12 Average Number of Mechanical Failures per Million Revenue Miles**

![Figure 13 Vehicle Usage Measured by Revenue Miles Served per Operated Vehicle](image2)

**Figure 13 Vehicle Usage Measured by Revenue Miles Served per Operated Vehicle**

**VEHICLE OPERATIONS AND MAINTENANCE EXPENSES**

Expenses reported in NTD are either for operations or capital investments. Operating expenses are reported in four categories: vehicle operations, vehicle maintenance, non-vehicle
maintenance, and general administration. The first two categories are expended on vehicles and are the focus of this section. Vehicle operations include all activities associated with dispatching and running vehicles in revenue service to carry passengers, including administrative and clerical support. Vehicle maintenance includes all the activities associated with ensuring revenue vehicles and service vehicles are operable, cleaned, fueled, inspected, and repaired. Non-vehicle maintenance includes all the activities associated with ensuring buildings, grounds, and equipment (garages, passenger stations and shelters, administration buildings); fare collection equipment; and communications systems, track, structures, tunnels, and power systems are operable. Finally, general administration includes all the activities associated with supporting the provision of transit service (NTD 2009).

Figure 14 shows the percentages of funds expended on each of the four categories. The figure shows that the percentages of funds expended on vehicle operations had been inching towards 60%. Together with vehicle maintenance, they accounted for nearly 80% of the total operating expenses. Figure 15 shows that the expenses (in 2009 dollars) per operated vehicle have clearly increased from 1995 to 2009, with expenses on vehicle operations increasing at the fastest rate. In contrast, expenses on vehicle maintenance have increased much slower. It can also be seen from the same figure that transit agencies spent significantly more on vehicle operation and maintenance per vehicle than outside contractors. In 2009, vehicle operation expenses for contracted vehicles are about 31% lower. For vehicle maintenance expenses, the difference was even lower, it was 44% lower. These results clearly show that, as far as the vehicle operation and maintenance cost are concerned, privatization could be a more financially efficient choice, especially for cash-strapped local governments. Note that in Figure 15, data are plotted for 1995 onwards because data prior to 1995 were not stratified by service types.

![Figure 14 Percent Distribution of Total Operating Expenses](image-url)
SUMMARY AND CONCLUSIONS

Investments in bus revenue vehicles are a major use of capital funds for transit agencies. This paper examined the national trends for seven characteristics specifically associated with bus revenue vehicles. They included vehicle fleet sizes, vehicle spare ratio, average vehicle age, average vehicle capacity, ADA-compliance, vehicle reliability, and vehicle operations and maintenance expenses. Using comprehensive data from an integrated system that provides access to the 1985 through 2009 National Transit Database (NTD), this paper has revealed a number of interesting national trends for these characteristics.

In terms of vehicle fleet sizes, it was found that nationally there was a significant increase starting from 1996 through 2009, which coincides with a period of increasing bus ridership. The trend in fleet sizes also showed that, nationally, there was a move over the years to privatize bus transit services. This could be interpreted as a positive trend by some considering that expense data showed that private service providers spent significantly less on vehicle operation and maintenance.

Two formulas have been used to calculate the average spare ratios which, individually, may yield very different numbers. As such, it is highly critical that one be aware of the specific formula(s) used when comparing spare ratios from different sources. The Federal Transit Administration (FTA) has suggested that the spare ratio should not exceed 20% for agencies operating 50 or more revenue vehicles. However, the results show that, nationally, this limit has been consistently exceeded.
The national trend in average fleet age showed that contracted bus vehicles tended to be newer than those operated directly by transit agencies, although the gap has narrowed in recent years. This narrowing of the gap appears to be largely a result of new vehicles purchased by transit agencies. In terms of vehicle design, the national trends showed a tendency to trade seats for more standing room, and a clear trend to convert vehicles with lifts to vehicles with ramps/low-floor for ADA accessibility. By 2006, nearly all bus vehicles were ADA-compliant. Another major improvement found was in the reliability of vehicles. This was evidenced from a reduction of over 200% in the number of mechanical failures per million revenue vehicle miles served between 1985 and 2004.

REFERENCES


