U.S. Department of Transportation
Federal Transit Administration

Federal Transit Administration

Useful Life of Transit Buses and Vans

Report No. FTA VA-26-7229-07.1

April 2007

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
April 2007

3. REPORT TYPE AND DATES COVERED
Final Report

4. TITLE AND SUBTITLE
Useful Life of Transit Buses and Vans

5. FUNDING NUMBERS

6. AUTHOR(S)
Richard Laver, Donald Schneck, Douglas Skorupski, Stephen Brady, Laura Cham
Booz Allen Hamilton

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Booz Allen Hamilton, Inc.
8283 Greensboro Drive
McLean, Virginia 22102

8. PERFORMING ORGANIZATION REPORT NUMBER
FTA

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Federal Transit Administration
U.S. Department of Transportation
Washington, DC 20590

10. SPONSORING/ MONITORING AGENCY REPORT NUMBER
FTA-VA-26-7229-07.1

11. SUPPLEMENTARY NOTE
Online at [http://www.fta.dot.gov]

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Available From: National Technical Information Service/NTIS, Springfield, Virginia, 22161.
Phone (703) 605-6000, Fax (703) 605-6900, Email [orders@ntis.fedworld.gov]

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
The Federal Transit Administration (FTA) sponsored this research to assess both the appropriateness of its existing minimum service-life policy for transit buses and vans, and the need to change that policy. The research evaluated the federal minimum service-life requirements based upon the actual experience of both transit operators and vehicle manufacturers. The analyses in this research provide the transit industry and the FTA with a better understanding of (1) the current useful life of transit buses and vans, (2) the appropriateness of FTA's minimum service-life policy, and (3) the policy's impact on transit vehicle life expectancies and vehicle retirement decisions at the agency level. Actual ages of buses retired from service generally exceed FTA minimums. Transit agencies interviewed cited availability of capital funds for bus replacement as the primary determinant of retirement age.

14. SUBJECT TERMS
Transit, Bus, Van, Useful Life, Engineering Analysis, Economic Analysis, FTA Bus and Van Minimum Service-Life Policy, Transit Fleet Retirement Age

15. NUMBER OF PAGES
195

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified

20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18298-102

NOTICE

FOREWORD

The Federal Transit Administration (FTA) sponsored this research to assess both the appropriateness of its existing minimum service-life policy for transit buses and vans, and the need to change that policy. The research evaluated the federal minimum service-life requirements based upon the actual experience of both transit operators and vehicle manufacturers. The analyses in this research provide the transit industry and the FTA with a better understanding of (1) the current useful life of transit buses and vans, (2) the appropriateness of FTA's minimum service-life policy, and (3) the policy's impact on transit vehicle life expectancies and vehicle retirement decisions at the agency level. Actual ages of buses retired from service generally exceed FTA minimums. Transit agencies interviewed cited availability of capital funds for bus replacement as the primary determinant of retirement age.

Author Acknowledgements

This report was authored by Richard Laver, Donald Schneck, Douglas Skorupski, Stephen Brady, Laura Cham, and Jeff Rankin of Booz Allen Hamilton. Valuable insight and direction was provided by Henry Nejako, John Bell, and Nancy Ody of the FTA. In addition, the authors would like to thank the staff of those transit operators and vehicle manufacturers who graciously provided their time and input to this study and without whom the study would not have been possible.

Table of Contents

EXECUTIVE SUMMARY

The Federal Transit Administration's (FTA's) service-life policy for transit buses and vans establishes the minimum number of years (or miles) that transit vehicles purchased with federal funds must be in service before they can be retired without financial penalty. The clear goal of this policy is to ensure that vehicles procured using federal funds remain in service for a substantial portion of their service life, thus ensuring that federal taxpayers obtain an adequate return on their investment.

Over time, perception of these requirements has become less as a *minimum* service-life requirement (to ensure a reasonable return on federal dollars invested) and more as the *actual* useful life (a point at which the asset should be retired). Given this change in interpretation, most industry experts commonly refer to a standard, 40-foot bus as a "12-year" bus, and many transit authorities have adopted 12 years as their retirement policy for this vehicle type. There is also a common perception within the industry that transit vehicle manufacturers, especially those working under low-bid procurements, now design their vehicles to meet, but not exceed, the 12-year minimum-life requirement. Hence, rather than defining a *minimum* life expectancy to ensure an adequate return on federal funds, the FTA's service-life policy has become viewed as the FTA's, and the industry's, expectation for the full service life of the vehicle—a view that may have impacted the actual life expectancy of the nation's transit fleets.

Table ES-1
Minimum Service-life categories for Buses and Vans

Category	Typical Characteristics				Minimum Life	
	Length	Approx. GVW	Seats	Average Cost	(Whichever comes first)	
					Years	Miles
Heavy-Duty Large Bus	35 to 48 ft and 60 ft artic.	33,000 to 40,000	27 to 40	$325,000 to over $600,000	12	500,000
Heavy-Duty Small Bus	30 ft	26,000 to 33,000	26 to 35	$200,000 to $325,000	10	350,000
Medium-Duty and Purpose-Built Bus	30 ft	16,000 to 26,000	22 to 30	$75,000 to $175,000	7	200,000
Light-Duty Mid-Sized Bus	25 to 35 ft	10,000 to 16,000	16 to 25	$50,000 to $65,000	5	150,000
Light-Duty Small Bus, Cutaways, and Modified Van	16 to 28 ft	6,000 to 14,000	10 to 22	$30,000 to $40,000	4	100,000

Study Goals and Objectives

FTA established its minimum life requirements for transit buses and vans in 1985. At that time, the requirements represented the consensus opinion of a broad range of industry representatives. Since then, the requirements have undergone only minimal changes and remain essentially unaltered. The objective of this study is to reassess FTA's existing minimum-life policy given the actual experiences of both transit operators and vehicle manufacturers. Key questions to be addressed by this review include:

- What are the actual ages (and mileages) at which operators are retiring their transit buses and vans, and how do those ages compare to the FTA minimums?
- Do the current minimum age and mileage requirements meet the needs of all agency types?
- How do FTA's current retirement minimums affect the purchase and retirement decisions of the nation's operators?
- How have changes in vehicle designs (e.g., low floor) and technologies (e.g., alternative fuels) affected the expected vehicle life?
- Should FTA consider changing the current minimums given the experience of the nation's transit operators and manufacturers?

This study seeks to provide answers to each of these questions, with the ultimate objective of assessing both the appropriateness of FTA's existing minimum service life policy for transit buses and vans and any potential need to change that policy.

Approach

To meet the needs of the study, the study team completed the following eight independent analyses. Each of these analyses aimed to provide a different perspective on: (1) the current useful life of transit buses and vans, (2) the appropriateness of FTA's minimum life policy, and (3) the policy's impact on transit vehicle life expectancies and vehicle retirement decisions at the agency level.

- **Review of FTA's Current Service-life Categories:** The study reviewed the definitions and the characteristics of the vehicles found in each of the five existing service-life categories. The objectives were to determine the appropriateness of the categories based on the similarities and dissimilarities of the vehicle types found in each category and to conduct a market analysis for each category (i.e., annual vehicle sales and transit's share of those sales).
- **Review of Procurement Regulations with Potential Service-life Implications:** The study reviewed federal legislation and circulars to identify federal requirements potentially affecting either the useful life or vehicle retirement decisions of the nation's operators of transit buses and vans. This review included FTA's bus testing regulations, the Americans with Disabilities Act (ADA), Buy America requirements, the Standard Bus Procurement Guidelines, and the Clean Air Act and its Amendments.
- **Analysis of Actual Retirement Ages:** The study used National Transit Database (NTD) data to determine the actual ages at which U.S. agencies are currently retiring each of the transit bus and van types. This analysis was then used to compare the average retirement ages with the minimum FTA age requirements for each vehicle category to determine how these minimums may be impacting local operator's vehicle retirement decisions.
- **Industry Outreach:** The study team conducted two sets of interviews with bus fleet managers, vehicle engineers, and procurement personnel from a sample of the nation's large, medium, and small-sized bus and van operators. The first set of interviews documented

industry concerns with the existing service-life policy and elicited suggestions on how or if that policy should be changed. A second set of follow-up interviews focused on engineering specific issues such as the impact of new vehicle designs on expected vehicle life.

- **Market Analysis:** Most transit bus and van components and many of the vehicles themselves are derived from the general truck and automotive market. Market analysis provides a perspective on transit's role and position within the broader truck and automotive market, with emphasis on where transit has the ability to influence component and overall vehicle life expectancy.
- **Engineering Analysis:** The engineering analysis examines the life expectancy of individual vehicle components and of the vehicle as a whole (i.e., the factors that determine overall vehicle useful life). This analysis then considers the appropriateness of the minimum life requirements for each vehicle category given the useful-life characteristics of each vehicle's component parts.
- **Economic Analysis:** This analysis identifies that point in the life cycle of each bus and van type at which total life-cycle costs are minimized. This point provides a financially logical age (mileage) at which to retire that vehicle. The identified minimum cost replacement ages are then placed in context with the results of the engineering analysis. The combination of these two perspectives helps illustrate factors that drive grantees' vehicle retirement decisions.
- **Review of Prior Useful-Life Studies:** The study reviewed prior useful-life studies completed by FTA and the American Public Transportation Association (APTA) with the objective of working to obtain more current answers to the same questions and to compare and contrast the findings of this study with those of prior efforts.

Key Findings

Each of the eight independent analyses yielded insights into the useful life of transit buses and vans and FTA's minimum service-life policy. Key findings from each of the various analyses performed for this study are outlined below.

Review of FTA's Current Service-Life Categories

The review of FTA's minimum service-life requirements yielded the following key findings:

- **Transit bus and van fleets are dominated by 12-year and 4-year vehicles.** Of the roughly 91,000 transit buses and vans currently in service at U.S. transit operators, more than 70,000 (about 78 percent) are 12-year vehicles; about 16,500 (18 percent) are 4-year vehicles; and the remaining 5 percent are divided between the 10-year, 7-year, and 5-year vehicle categories.
- **The current service-life category groupings are appropriate.** A key study objective was to assess the appropriateness of the existing service-life categories (i.e., whether these categories "make sense"). The study found that the categories represent logical groupings of vehicles having broadly similar characteristics in terms of construction methods, size, weight, passenger capacities, cost, manufacturers, and customer bases (see Table ES-1 above). A possible exception here is with 4-year and 5-year vehicles built using cutaway chassis where

there is a significant degree of overlap between the two age categories in terms of construction type, sizes, and manufacturers. However, the similarities are not adequate grounds for combining the two into a single “4-to-5-year” vehicle category.

- **The transit industry has little ability to alter bus and van useful-life characteristics cost-effectively.** Nearly half of the vehicle components for 12-year buses and most components for all other vehicle categories (including the vehicles themselves) are obtained from either the heavy-truck or automotive markets. Given its small share of these markets (typically less than one percent), the transit industry has little ability to influence component useful-life characteristics in a cost-effective manner. A key exception here is the structure of 12-year buses. To the extent that 12-year bus structures are designed specifically for transit use, the transit industry has some leverage to influence this component’s design and durability characteristics. (However, given the manufacturers’ small annual order sizes and tight local agency capital budgets, funding such innovation is challenging in practice.) For most other components and vehicle types (e.g., minivans and cutaway chassis), the transit industry cannot significantly alter the useful-life characteristics without incurring the cost of customizing mass-produced items to meet transit-specific needs.

Review of Procurement Regulations with Potential Useful-Life Implications

While many federal regulations (e.g., Buy America, Bus Testing, ADA, Environmental Protection Agency) and industry procurement practices (third-party contracting) are believed to have potential useful-life implications, these implications are generally considered to be minor relative to the issues of annual mileage, new vehicle designs, changing life-cycle economics, and other drivers of useful life. A key exception here is the low-bid procurement process, which can yield vehicles with lower quality structures leading to reduced longevity. To protect against this outcome, agencies need to establish firm structural component requirements during the pre-bid stage to ensure the minimum-life requirements are attained.

Analysis of Actual Retirement Ages

The study used NTD data to determine how recent *actual* retirement ages for transit buses and vans compare with the FTA’s current *minimum* service requirements for transit buses and vans and whether these requirements affect the vehicle retirement decisions of the nation’s transit operators. **Table ES-2** summarizes this analysis.

Table ES-2
Minimum versus Average Retirement Age by Vehicle Category

Vehicle Category/ Minimum Retirement Age	Average Retirement Age (Years)	Share of Active Vehicles That Are:	
		One or more years past the retirement minimum	Three or more years past the retirement minimum
12-Year Bus	15.1	19%	9%
10-Year Bus	*	7%	4%
7-Year Bus	8.2	12%	3%
5-Year Bus/Van*	5.9	23%	5%
4-Year Van	5.6	29%	10%

* Average retirement age estimates for this vehicle category suffers from small sample issues

The analysis yielded the following key findings:

- **Most buses and vans are retired well after minimum service-age requirement is satisfied.** With one exception, Table ES-2 shows that, on average, transit buses and vans are retired between one to three years after their minimum service-life requirement has been satisfied. The exception is the 10-year bus category, where small sample issues prevented determination of a reliable average retirement age value (hence, it remains unclear how far past the minimum service-life requirement this vehicle type is typically retired). In addition, Table ES-2 demonstrates that a significant proportion of buses and vans remain in service at least one year past the retirement minimum (e.g., 20 percent of heavy-duty, 12-year buses), with many still in service three or more years past the minimum requirement (e.g., one in 10 "12-year" buses in active service are age 15 or older).
- **Minimum service age does not constrain agencies' vehicle retirement decisions.** Based on this and other analyses conducted using NTD data, it is clear that relatively few transit buses and vans are retired right at the minimum service age requirement. Thus, the current retirement minimums are not constraining the vehicle retirement decisions of the vast majority of the nation's bus and van operators (a finding confirmed in the agency interviews described below). Given this observation, it is also clear that any reduction to the current minimum-age requirements (e.g., from 12 to 10 years for a "12-year bus") would not result in any significant increase in the rates of retirement for the five service-life categories.

Industry Outreach

The included interviews of representatives of local transit operators, vehicle manufacturers, and private bus fleet operators to assess their current experiences with bus and van useful life as well as FTA's minimum service-life requirements. Questions covered areas such as vehicle replacement decisions, alternatives to the current FTA policies, maintenance practices, and the impacts on service quality. The following are key findings from this industry outreach process:

- **Most agencies have vehicle service-life policies.** All nine of the agencies completing the detailed interviews reported having either a service-life policy or a planned retirement age for heavy-duty, 12-year buses. For four of the agencies, the planned retirement age exceeds the FTA minimum of 12 years (with the Los Angeles County Metropolitan Transportation Authority at 13 years, the Washington Metropolitan Area Transit Authority and Jefferson Transit at 15 years, and the Toronto Transit Commission at 18 years).
- **Actual retirement ages generally exceed both FTA minimums and agency service-life policies.** The actual timing of vehicle retirement for all nine agencies typically occurs between one to four years after the FTA minimum has been reached (but can occur as late as vehicle age 20). Moreover, for most agencies, the recent actual retirement ages also exceed the planned or policy retirement ages. Given these observations, it is clear that FTA's current minimum service-life requirement for heavy-duty buses does not actively constrain the agencies' retirement decisions (as retirements occur after the minimum retirement age has been reached). None of the agencies reported having to take advantage of FTA's "like-kind exchange" provision permitting early retirement of specific vehicles.
- **Capital funding availability is the primary determinant of retirement age.** Limited capital funding was cited as the primary reason that the timing of actual vehicle retirements

has exceeded the planned/policy retirement age (and FTA service minimums) by all but one of the responding agencies. Because of this, the average fleet age is more likely to be impacted by the increased availability of federal funding than by any relaxation in the minimum service-life requirements. Other decision factors included service reliability, vehicle condition, vehicle maintenance, physical and local environmental conditions (salt intrusion), procurement process (low bid or negotiated), and duty cycle (mainly operating speed).

- **Only large agencies operating in "severe" urban environments perform scheduled mid-life overhauls.** Only the larger, urbanized agencies interviewed (Massachusetts Bay Transportation Authority, New York City Transit, Toronto Transit Commission, and Washington Metropolitan Area Transit Authority) perform comprehensive, "mid-life" overhauls of their heavy-duty cycle vehicles, stating that these overhauls are required to obtain service lives of 12 years or more given the tough service environments in which they operate. In contrast, none of the other agencies interviewed (including Los Angeles County Metropolitan Transportation Authority and Houston Metro) regularly complete a mid-life overhaul, with most suggesting it is not cost effective for them.
- **Most agencies have needed to retire vehicles early.** Most of the agencies have had to retire vehicles prior to their scheduled or desired retirement age. The causes of these early retirements range from unexpected declines in vehicle condition, high maintenance costs, equipment upgrades, or damage beyond repair. Most agencies would support the introduction of a policy variance for particularly troublesome procurements, but were equally concerned about how FTA could control the review and approval process.
- **Most agencies have not been impacted by FTA's service-life requirements.** Most interviewed agencies stated that their vehicle retirement decisions are not significantly impacted by FTA's service-life minimums (the decisions are constrained more by capital funding availability). The agencies did suggest that more category options may be advantageous in the future to reflect differences in expected vehicle life as new vehicle designs and technologies are introduced (e.g., for bus rapid transit).
- **Extending the service-life requirements would hurt many agencies.** Conversely, most (if not all) of the agencies reported that they would be negatively impacted if current FTA service-life minimums were extended. These negative impacts include a decrease in service quality (e.g., higher failures rate, vehicle aesthetic, and reliability), an increase in maintenance costs (between 10 to 50 percent higher), and less leeway to retire "problem" vehicles.
- **Agencies support development of a "lemon law" and a technology demonstration option.** Interview respondents supported development of a "lemon law" and a technology demonstration option. The lemon law concept would permit early retirement of problem vehicles without penalty to the agency. All respondents agreed that this provision would need to clearly specify the conditions under which vehicles could be retired early and/or define a clear FTA process for evaluating whether a vehicle is, in fact, a "lemon." Under the technology demonstration concept, a grantee could request a similar release from the service-life policy for FTA-approved tests of new vehicle technologies that would allow the agency to discontinue operation of the vehicle if the technology proved too problematic. FTA could

approve this on a selective basis through documentation of the demonstration results and industry dissemination.

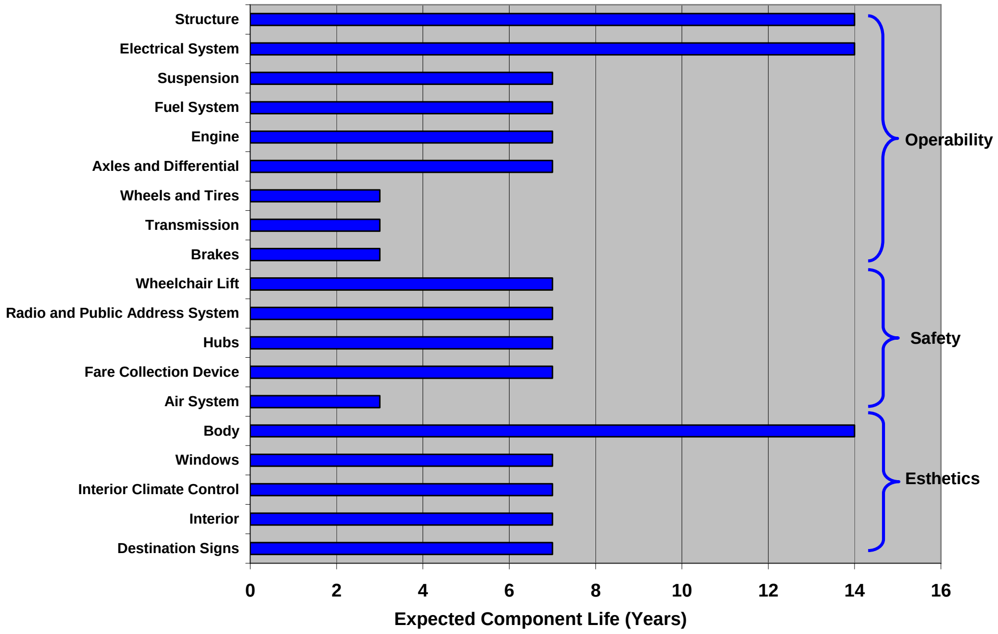
- **Most agencies are not interested in more or less durable heavy-duty vehicles.** Interview respondents were asked to consider their agency's interest in heavy-duty vehicles with longer, shorter, or other service-life characteristics. They responded as follows:
  - *More Durable (Longer Life) Heavy-Duty Vehicles:* Most agencies indicated that they were not interested in a more durable vehicle (i.e., with a more expensive, heavier weight, longer life expectancy structure). This is due to concerns over the cost effectiveness, weight, and rider comfort for this option. Some agencies stated a more durable vehicle type might be considered if its components were equally durable.
  - *Less Durable (Shorter Life) Heavy-Duty Vehicles:* All nine agencies expressed significant concerns with a less durable vehicle (i.e., with a cheaper, lighter weight, lower life expectancy structure). Concerns involved the vehicle's anticipated inability to survive the required duty cycles, relationship with the expected life of components, and decreased quality, and the increase in procurement efforts.
  - *Agency-Determined Retirement Age:* None of the agencies objected to the alternative option of allowing agencies to use their own judgment in determining vehicle retirement ages (i.e., drop all minimum life requirements and rely on funding constraints to ensure vehicles are retained for reasonable service lives). Based on the current actual retirement ages of the nine agencies, few agency vehicles would be retired before the current FTA's current minimums (due to funding constraints).

Engineering Analysis

The engineering analysis provides further evaluation of bus useful life from a vehicle engineering perspective. The following are key findings:

- **Useful life is ultimately determined by the life of the vehicle structure.** Relatively few vehicle components typically last the full "service life" of the vehicle. For 12-year vehicles, this includes the structure, exterior, and electrical system (see Figure ES-1). Vehicle structure as a whole defines the useful life of the vehicle more than any other single vehicle component. The reason being that the structure is the backbone to which all other vehicle components are ultimately attached. If the structure wears out or fails due to corrosion or a collision, then the life of the vehicle is essentially at an end.
- **Service environment is a key determinant of structure useful life.** In addition to vehicle age and service miles, many interview participants clearly indicated that service environment is a key determinate of structure (and hence vehicle) useful life. Vehicle structures that endure high passenger loads or operate in more severe service environments (e.g., rough urban roads) wear out faster. Because of this, several agencies expressed a desire for FTA to revise the service-life requirements definition to include service environment severity, along with service years and miles (e.g., 12 years or 500,000 miles). This desire was also identified in prior reviews of bus service life, including the 1995 Bus Industry Summit.

Figure ES-1
Component Expected Life: 12-Year Bus



- **"Stick bus" and low-floor vehicles may have a shorter useful life.** Interview participants suggested that stick bus (structures constructed using hundreds of welded tubes) and low-floor designs (which use stick construction) may have a shorter useful life as compared to traditional designs. With the stick bus, the thousands of welds that hold the structure together are more subject to corrosion and fatigue—an issue that manufacturers have largely addressed using corrosion-resistant coatings, stainless steel, and design strengthening. Interview participants stated that it is too early to determine whether the low-floor design will impact vehicle longevity, but noted that this design is more susceptible to road-side damage and salt spray (as the floor structure is closer to the ground).
- **New propulsion systems and electronics technologies may also impact useful life.** While engines for compressed natural gas and hybrid electric buses are expected to have similar useful lives compared to diesel, these two engine types weigh more than diesel engines, which may have an impact on structural wear (this has yet to be determined in practice). Similarly, the rapid proliferation of new electronics technologies on buses (such as automatic vehicle location, automatic passenger counters (APCs), on-board cameras, and voice annunciation) may have implications for useful life as the presence of so many systems increases the likelihood of reliability issues. Again, the actual impact on useful life has yet to be determined in practice.

Economic Analysis

For all vehicle categories, the economic analysis identified the age at which total life-cycle costs, including all capital, operating, and maintenance costs, are minimized (reflecting the impact of differences in mileage). This analysis identifies a financially optimal retirement point for the vehicle. **Table ES-3** summarizes the results of this analysis.

Table ES-3
Minimum Life-Cycle Cost Replacement Ages and Mileages by Service-Life Category

Vehicle Type / Category	Annual Vehicle Mileage	Minimum Cost Age	Minimum Cost Mileage
Heavy-Duty Large Bus: 12-Years / 500,000 Miles	25,000	17	425,000
	35,000	14	490,000
	45,000	12	540,000
Heavy-Duty Small Bus: 10-Years / 350,000 Miles	25,000	12	300,000
	35,000	11	385,000
	45,000	11	495,000
Medium-Duty Small Bus: 7-Years / 200,000 Miles	25,000	9	225,000
	35,000	8	280,000
	45,000	7	315,000
Light-Duty Midsize Bus/Van: 5-Years / 150,000 Miles	20,000	7	140,000
	30,000	6	180,000
	40,000	5	200,000
Light-Duty Small Bus/Van: 4-Years / 100,000 Miles	20,000	6	120,000
	30,000	5	150,000
	40,000	4	160,000

Note: Shaded cells indicate where minimum cost point exceeds FTA age or mileage minimums.

The following are key findings:

- **The minimum cost retirement points all occur at or after the FTA minimum service life.** Table ES-3 suggests that, from a cost-effective perspective, FTA's current service-life minimums, including both the minimum years and miles requirements, represent reasonable choices. For each service-life category, the minimum cost point is attained at either an age or mileage that exceeds one or both of the FTA minimums for these measures. In all cases, the difference between one or both of the current FTA minimum requirements and the minimum cost age or mileage also provide some margin for the earlier retirement of vehicles with reliability problems. This suggests that current age and mileage service-life minimums represent financially sound minimum-life choices.
- **Reducing heavy-duty vehicles service life from 12 to 10 years would only have a minimal impact on vehicle sales.** At most, 10 percent of all retirements for heavy-duty buses occur right at vehicle age 12, translating to an average of roughly 200 to 300 annual retirements potentially constrained by FTA's minimum-life requirements. Assuming vehicles retiring at the current 12-year minimum shifted to a new 10-year minimum, the long-term, average annual replacement rates for these operators would increase from 200 to 300 vehicles to 240 to 360 vehicles annually, or 40 to 60 additional vehicles per year. Given that deliveries of new buses average roughly 3,000 per year and the industry's estimated total vehicle production capacity of 7,500 to 10,000 vehicles, the addition of 40 to 60 new vehicles is far from significant. Hence, reducing useful life for heavy-duty vehicles by two years is unlikely to yield a significant boost to the small domestic bus market.
- **Reducing heavy-duty service life from 12 to 10 years would have a minimal impact on ridership and service reliability.** Given that so few vehicle retirements are currently

constrained by FTA's current service-life policy, any reduction is unlikely to drive significant improvements in ridership levels or service reliability. Note, however, that the relationship between vehicle condition and ridership is not well understood, and FTA may wish to sponsor studies to better evaluate this issue.

Recommendations

Based on the findings above, it is recommended that FTA consider the following:

- **Maintain the current service-life minimums:** Few buses and vans are currently retired right at FTA's current service-life minimums. Rather, the vast majority of these vehicles are retained in service for at least one year (4- and 5- years vehicles) and as many as three or more years (e.g., for 12-year vehicles) after the minimum service requirements have been met, indicating that these vehicles have some service life remaining beyond the minimums. Moreover, the current service-life age and/or mileage minimums for all vehicle types occur *before* the minimum life-cycle cost points for these vehicles are reached. Hence, the current service-life minimums clearly meet the joint objectives of (1) ensuring that buses and vans purchased using federal dollars remain in service for most of their useful life, (2) of providing agencies some flexibility in determining when their vehicles will be retired and (3) of helping to minimize life-cycle costs. In this sense, the current service-life minimums really are just that, the *minimum* ages at which vehicles can be retired—not a recommended retirement age or a measure of actual expected useful life. The current minimum service-life requirements should be maintained.
- **Maintain the current service-life categories:** Similarly, the segmentation of transit bus and van types into the current five service-life categories reflects actual similarities in vehicle structures, designs, components, costs, origin markets, manufacturers, and end users. These current categories should be maintained.
- **Review the service-life minimums and service-life categories regularly:** The analysis of recent changes in vehicle designs, the adoption of new technologies, and the introduction of new vehicle types (e.g., stainless-steel bus rapid transit vehicles) highlight the fact that the service-life characteristics of transit buses and vans are subject to change. For this reason, FTA should review the minimum life requirements and service-life categories on a regular basis (e.g., every 5 to, at most, every 10 years).
- **Adoption of a "lemon law":** This law would define circumstances under which "problem" vehicles could be retired early without financial penalty.
- **Adoption of a technology demonstration option:** Similar to the "lemon law," this option would define circumstances under which agencies could retire vehicles purchased to test new technologies (with FTA's prior agreement) early—without financial penalty. The intention would be to encourage test and adoption of new, but potentially unreliable, technologies expected to benefit the entire transit industry.
- **Restrict the service-life categories in which vehicles are tested:** In recent years, some manufacturers have successfully lobbied to have their vehicles tested in a more durable category than would appear warranted by their vehicle's general characteristics (e.g., testing a bus with 10-year characteristics as a "12-year" bus). This has resulted in service reliability

issues and, in some instances, early retirement for the purchasing agencies when the tested vehicles were not found to have the expected durability. Thus, FTA may wish to more tightly control the categories in which vehicles are eligible to test based on some combination of characteristics (e.g., gross vehicle weight and seating capacity), but with the potential for special waivers to test in a different category so as not to stifle innovation. (Manufacturers should be required to provide reasonable justification as to why their vehicles should be tested in the higher durability category.)

- **Modify the NTD reporting requirements to better document actual vehicle retirement age and each vehicle's assigned service-life category:** The analysis used in this study to determine actual vehicle retirement ages relied on cross comparisons of NTD data from multiple reporting years. FTA should modify NTD to track the actual age of vehicle retirements, thus significantly improving FTA's ability to track and monitor any trends in vehicle retirement ages. Similarly, NTD's vehicle documentation should also include the service-life category to which each vehicle has been assigned (again to facilitate monitoring of the retirement ages for each service-life category).
- **Conduct a study to evaluate the sensitivity of bus ridership to changes in vehicle age and condition:** A key objective of this study was to consider how bus ridership might change (increase) in response to a reduction in the average age of the nation's bus fleets (e.g., with the introduction of a new, shorter-lived, heavy-duty transit vehicle). However, while review of the existing literature provides numerous references to the sensitivity of ridership to changes in fares and service frequency, no literature references were identified that provide a quantitative link between ridership and fleet age or condition. In the absence of solid empirical data linking ridership and fleet age, any analysis of this relationship can only be based on conjecture and limited anecdotal evidence. For this reason, the study team recommends that FTA conduct a study to evaluate the sensitivity of bus ridership to changes in vehicle age and condition. Given the availability of good-quality, route-level ridership data (from electronic fare boxes and APCs), this study could easily be conducted using a sample of U.S. transit operators, using before and after comparisons of which older sub-fleets have been replaced by new (or newer) vehicles.

CHAPTER 1. INTRODUCTION

Background

Transit agencies purchasing transit buses and vans using federal capital funds are required to keep these vehicles in service for a minimum period of time (years) and/or number of miles prior to that vehicle's retirement to ensure effective use of federally funded assets. This minimum service-life requirement differs based on bus and van size and other characteristics and is specified in FTA Circular 9030.1B. The requirements currently recognize five different service-life categories (see **Table 1-1**).

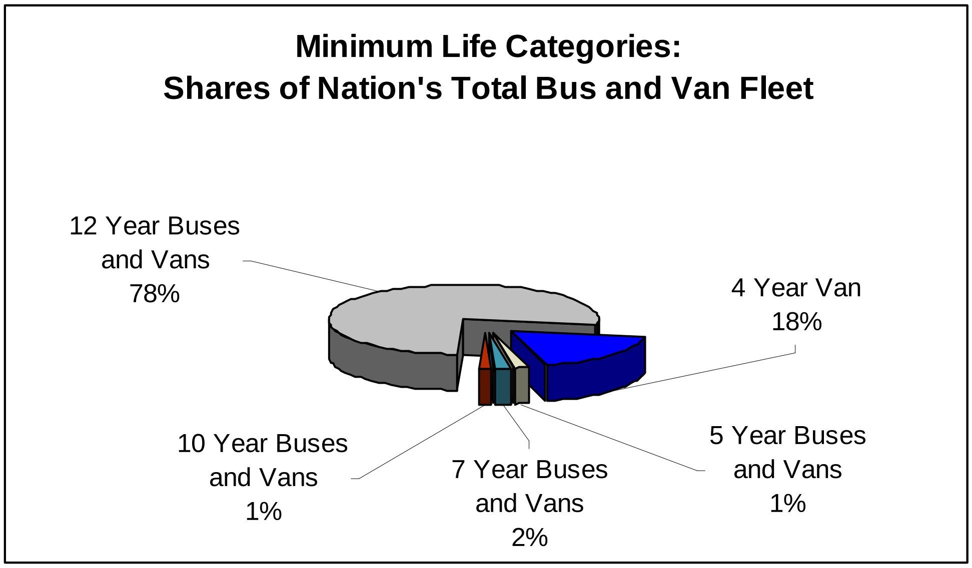
Table 1-1
Minimum Service-Life Categories for Buses and Vans

Category	Minimum Life (Whichever comes first)	
	Years	Miles
Heavy-Duty Large Bus	12	500,000
Heavy-Duty Small Bus	10	350,000
Medium-Duty and Purpose-Built Bus	7	200,000
Light-Duty Mid-Sized Bus	5	150,000
Light-Duty Small Bus, Cutaways, and Modified Van	4	100,000

The relative abundance of vehicles within these different categories varies significantly (see **Figure 1-1**). As might be expected, 12-year buses account for more than three-quarters of all U.S. transit buses and vans, while 4-year vehicles account for nearly one-fifth of vehicles. The remaining vehicle types, including 10-, 7-, and 5-year vehicles, collectively account for less than 5 percent (one in 20 vehicles) of the nation's transit bus and van fleet. The limited number of vehicles, and relatively shallow depth of the market for 10-, 7-, and 5-year vehicles (roughly 4,000 vehicles out of a total of more than 90,000 transit buses and vans nationwide), make it difficult to effectively assess the actual useful-life characteristics of these less popular vehicle types. In contrast, agency and industry data sources have relatively good quality data on the useful-life experiences of the 12- and 4-year vehicle types.

Since its inception, several issues have been raised regarding FTA's minimum service-life policy. These include the vehicle category definitions, the use of vehicle age or miles (or hours) as the basis for defining service life, and the potential for extended life cycles through life-extending overhauls. More generally, the question arises as to whether the current minimum life ages and mileages are appropriate given the experiences of the nation's operators of transit buses and vans.

Figure 1-1



Study Objectives

The aim of this study is to reassess FTA's existing minimum service-life policy (including both the actual minimum age and mileage requirements and the service-life categories into which bus and van vehicles are placed) based on the experiences, vehicle retirement practices, and life-cycle cost characteristics of the nation's transit operators and vehicle manufacturers. Key questions to be addressed by this review include the following:

- What are the actual ages (mileages or service hours) at which operators are retiring their transit buses and vans, and how do those ages compare to the FTA minimums?
- Do the current minimum age and mileage requirements meet the needs of all agency types?
- How do FTA's current retirement minimums affect the purchase and retirement decisions of the nation's operators?
- How has other federal legislation, such as "Buy America," impacted vehicle bus and van useful life, if at all?
- Should FTA consider changing the current minimums given the experience of the nation's transit operators and manufacturers? Alternatively, how would an increase or decrease in the current minimum life requirements affect the fleet investment decisions of the nation's transit operators?
- Are operators interested in procuring vehicles with shorter life expectancies than are permitted by the current policy (e.g., a cheaper and shorter life expectancy 40-foot bus)?
- How have changes in vehicle designs (e.g., low floor) and technologies (e.g., alternative fuels) affected the expected vehicle life?
- How do vehicle procurement policies impact expected vehicle life?

This study seeks to provide answers to each of these questions, with the ultimate objective of assessing both the appropriateness of FTA's existing minimum service-life policy for transit buses and vans and any potential need to change that policy.

Reasons for Reviewing the Service-Life Policy

More than 20 years have passed since the adoption of FTA's minimum service-life guidelines. Since that time, the industry has undergone several significant changes, many with potential implications for vehicle useful life. Among these are the following:

- **Operator Experience and Changing Economics:** The current minimum service-life requirements were developed based on the industry's understanding of useful life as of 1985. With two decades of experience operating under these requirements, operators have developed their own impressions and opinions as to how these requirements align with actual useful-life experience. Moreover, even if it is assumed that there have been no changes to the buses themselves (which, of course, there have been), changes to capital and operating costs as well as to vehicle utilization (passenger loads and duty cycles) will have yielded changes to both the economic and physical determinants of vehicle useful life.
- **Impact of the Policy Itself:** It has been suggested that the presence of FTA's vehicle service-life policy has itself impacted actual useful-life expectations. For example, the combination of the low-bid and minimum life requirements may have yielded buses designed specifically to meet, but not exceed, the minimum life requirement (e.g., thus reducing the total expected useful life of a 40-foot bus from 14 to 16 years to, say, 12 years). Alternatively, many manufacturers have lobbied to have their vehicles moved to a higher minimum age category (e.g., 10-year buses re-categorized to 12-years) as a means of expanding the potential market for their product. There is now some evidence that this practice may have yielded buses that are capable of meeting the higher category bus testing requirements and yet not capable of meeting the service-life minimums once in service.
- **New Vehicle Designs and Materials:** The past 20 years have seen the introduction of many new vehicle designs including increasing use of differing vehicle lengths (from 60 foot articulated to 30 foot sizes for 12-year buses, and a similar range of sizes for 10-year, 7-year, and 5-year vehicles); low floor buses; and "stick" buses using a network of welded tubes in place of more traditional structures. Each of these design variations, especially those with changes of structural significance, has implications for expected vehicle life.
- **Alternative Fuels:** Operators have also increasingly adopted the use of alternative fuels vehicles including compressed natural gas (CNG), duel-fuel, gas, hybrid, and potentially fuel cell vehicles. Some of these are coming to the end of their first full life cycle, thus providing an opportunity to assess their impact on vehicle useful life.
- **New Technologies:** The past 5- to 10-year period has seen a significant increase in the number of new technologies installed on transit buses. These include automatic vehicle location (AVL), automatic passenger counters (APCs), voice annunciation, on-board cameras, multiplexers, and potentially collision avoidance systems. Assuming many or all of these systems are expected to function before a vehicle can be released for revenue service each day, the sheer proliferation of the technologies, and the increasing likelihood that any

one of them will fail as the vehicle ages, has significant implications for vehicle useful life. From another perspective, the increasing desirability of having the latest suite of technologies on each fleet vehicle can also drive down the useful life of transit vehicles, with life here being determined more by technological obsolescence than by asset wear.

- **Changes to the Domestic Manufacturing Market:** The combined influences of wide production variances, Buy America provisions, and the exit of several suppliers has significantly affected the long-term structure and viability of the domestic bus market. The changes have yielded uncertainty regarding the future of exiting manufacturers and also impacted the availability of replacement parts for (and hence maintainability of) older fleet vehicles.
- **Legislation:** In addition to Buy America provisions, bus suppliers and purchasers are subject to a variety of additional federal requirements that may impact vehicle useful life. Among these are the Bus Testing, ADA, and EPA emissions requirements.
- **Procurement Strategies:** While transit operators continue to use a variety of vehicle procurement strategies, the use of low-bid procurements in particular may have a negative impact on vehicle useful life. Moreover, as discussed elsewhere in this study, the relatively small size of individual agency procurements (and the small size of the transit market in relation to the broader truck and automotive market) gives transit operators and the industry as a whole little ability to directly impact the useful-life characteristics of many bus and van types or their components.
- **Desire to Increase Ridership / Service Quality:** FTA’s policy objective of increasing ridership might be served by accelerating the removal of older vehicles from service (thus improving the quality of service). As noted above, such an accelerated replacement cycle could similarly quicken the adoption of new technologies, further enhancing the rate of service improvement.

Each of these considerations supports a reassessment of FTA’s current minimum service-life requirements. This study duly reviews each of these considerations.

What is Useful Life?

Before reviewing the study analyses and results, it is helpful to first establish a working definition of useful life—a concept that has different meanings to different users. Useful life is typically defined as that age (i.e., number of years) after which an asset is no longer “fit for use” in the sense that it has become worn, not fully operational, unreliable, and/or does not otherwise deliver transit service of acceptable quality. For mechanical assets, such as transit vehicles, the total *utilization* of that asset (e.g., life to date vehicle miles or hours) is equally important to *age* when establishing a minimum useful life. Useful life based on asset utilization depends on the asset type, its design specifications, and the service it performs. For transit buses and vans, it is clear that total vehicle miles is, in most instances, a better measure of asset ware than vehicle age (with the latter frequently functioning as a rough proxy for the former). An empirical analysis of the relationship between useful life expectancy in years and vehicle life-to-date mileage for U.S. transit buses is demonstrated in Chapter 7 (and repeated again later in the report using financial analysis). These analyses underscore the importance of maintaining a combined age- and mileage-based FTA service-life policy.

Engineering-Based Bus Conditions

For transit buses, it is not sufficient to be merely “operational.” Rather, transit patrons expect a vehicle that is reliable, safe, and offers reasonably comfortable travel. The problem lies in identifying a specific point in the asset’s life (age or service miles) at which service quality, safety, or reliability is no longer acceptable. In reality, the decline in condition of a transit vehicle is a slow, continuous process (excepting the impact of major overhauls) with no obvious point of retirement. What is acceptable to one transit patron may not be to another.

Figure 1-2 highlights both the absence of an obvious retirement age based on physical condition alone as well as the effect of vehicle use on vehicle condition. In support of model development for the Transit Economic Requirements Model (TERM), FTA has conducted detailed physical condition inspections of more than 900 transit bus and van vehicles at more than 40 different transit agencies nationwide (each inspection is represented by a point in Figure 1-2). The sloping lines in Figure 1-2 represent vehicle decay curves developed using this data for the 12-year and 4-year service-life categories. Here, overall vehicle physical condition is measured on a scale of 5 (excellent) through 1 (poor). The trend lines capture the rate of vehicle decay.

The inspections revealed both a slow decline in vehicle physical condition (and related service quality and reliability) with age and (for each age) a wide variation in condition driven primarily by differences in vehicle mileage and maintenance practices (captured here by the spread of vehicle condition observation points), but no obvious age or condition value for vehicle retirement. Hence, while these condition/age relationships are extremely valuable in understanding and predicting the rate of physical decay for transit vehicles, they cannot be used to identify a *specific* desired retirement age or condition. As a point of reference, most transit operators replace their vehicles somewhere between condition 2.0 to 2.5 on this chart.

Cost-Based Useful Life Analysis

In contrast to this condition-based approach, vehicle cost analysis can be used to identify a specific vehicle retirement age (or service miles) at which average annual life-cycle costs for each vehicle type are minimized. For example, the “minimum life-cycle cost” approach employed in this report (see Chapter 7) compares the decline in purchase cost per service mile over the life of a vehicle with the corresponding increase in operating and maintenance costs (as well as periodic engine, transmission, and other rehabilitation activities). The period in time at which the sum of these annualized capital and operating costs is minimized represents the financially optimal point for vehicle retirement. Unlike the engineering-based condition assessment, this method identifies a specific optimal point in the asset life cycle for vehicle retirement. However, while the engineering-based assessment does not provide a specific useful-life age, it does recognize declining service quality with age (which financial considerations alone do not). **Table 1-2** outlines the tradeoff between these two approaches.

Figure 1-2

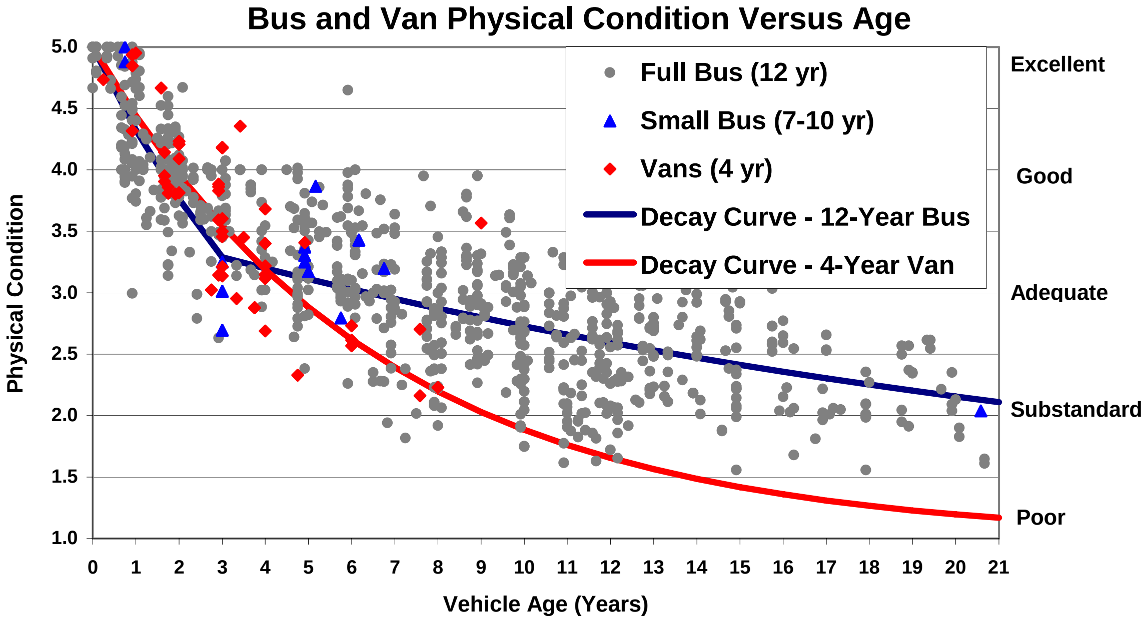


Table 1-2
Engineering Versus Economic Approaches to Identifying Useful Life

Approach	Measures Service Quality?	Identifies a Specific Useful-Life Value?
Engineering: Condition Based	Yes	No
Economic: Minimum Cost Replacement	No	Yes

Minimum, Optimal, Expected and Average Useful Life

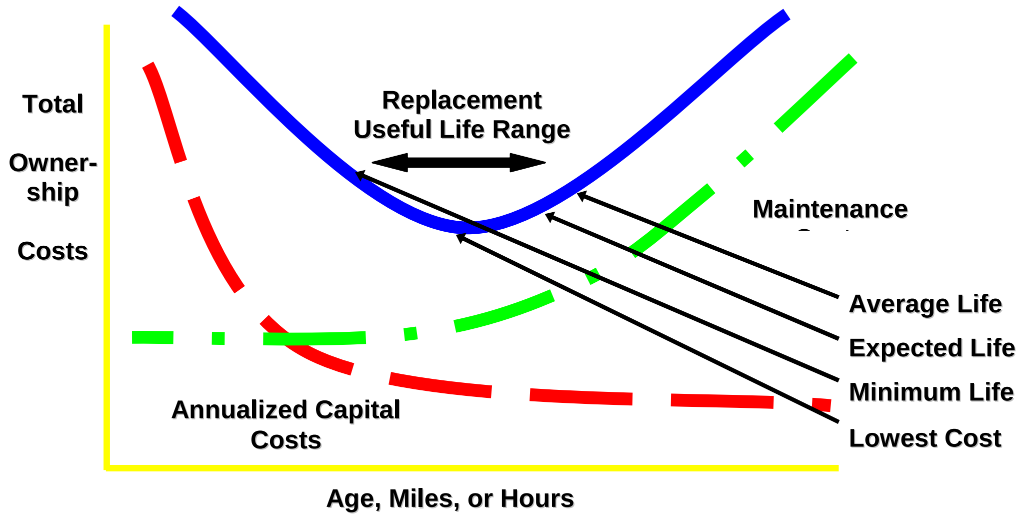
Finally, this study frequently makes the distinction between four different concepts of useful-life including optimal useful life, expected (or planned) useful life, minimum useful life, and the current average retirement ages for U.S. transit buses. **Table 1-3** presents these concepts and their definitions. Understanding the differences in these definitions is important to understanding the analyses in the succeeding chapters of the report and also has importance to any potential changes to FTA's current service-life minimums. These concepts are also illustrated graphically in **Figure 1-3**.

The distinctions between the definitions in Table 1-3 are more than semantic. Many within the transit industry equate FTA's 12-year *minimum* with the *expected* or desired useful life of a large transit bus (indeed, many of the agencies participating in this study have set their agency's *expected* useful life values equal to the FTA *minimum*). This rather then viewing the 12-year minimum as a point at which some useful-life remains. **From the viewpoint of establishing policy, it is recommended that FTA continue to establish its service-life *minimum* requirements such that some useful life does remain and yet the majority of useful life has been consumed.** Under these circumstances, the *expected*, *average*, and *optimal* useful life values for each transit bus and van type should each occur **after** the service-life *minimum* (as is currently the case based on the results of this study). Maintaining this policy will ensure that (1) tax payers derive good value from funds invested in transit buses, (2) agencies with higher than average vehicle wear rate characteristics (i.e., their expected and optimal useful lives are lower than the average) will have some leeway for earlier retirement, and (3) agencies with a “problem” vehicle model will also have some leeway for earlier retirement. (Chapter 5 considers provisions for more highly problematic vehicle models.)

Table 1-3
Vehicle Useful Life Concepts

Useful Life Concept	Definition	Example Based on “12-Year” Bus
Expected or Planned Useful Life *The age at which agencies “expect” or “plan” to retire their vehicles*	The age at which transit operators plan to retire their transit vehicles under the assumption that these assets will be completely worn	For many agencies, this point is driven by policy and/ or funding availability and occurs at age 12 to 15
Average Useful Life *The age at which agencies “do” retire their vehicles*	The average age at which U.S. transit operators “actually” retire their transit vehicles	Based on analysis of NTD data presented below, the average retirement age is 15.1 years.
Optimal Useful Life *The age at which agencies “should” retire their vehicles*	The financially optimal point for vehicle retirement (i.e., the point at which life-cycle costs are minimized)	Based on the analysis in Chapter 7, this occurs between 12 to 14 years depending on annual mileage and other factors
Minimum Useful Life *The minimum age at which agencies are “allowed” to retire their federally funded vehicles without penalty*	The *minimum* age/mileage to retire a vehicle. This point assumes that most vehicles still have additional years of useful and cost-effective service but that most of the asset’s value has been consumed	Currently set at 12 years

Figure 1-3
Minimum Life-Cycle Cost Curve



Finally, the upcoming chapters of this report investigate and assess each of these differing useful life measures based on the survey responses, vehicle retirement activities, and life-cycle costs of U.S. transit operators. Specifically, Chapter 4 documents *average* useful life of all transit bus and van categories based on actual vehicle retirements as obtained from FTA's National Transit Database (NTD). Next, Chapter 5 documents the *expected* useful life of the nation's transit buses based on agency responses to a survey conducted for this study. Finally, Chapter 7 estimates the *optimal* useful life based on a minimum life-cycle cost analysis of each bus and van type. The study then compares and contrasts the assessed values for each of these differing measures of useful life with FTA's current service-life *minimums* to assess the appropriateness of those minimums and any potential need to change them.

What About Vehicle Hours?

Finally, FTA's minimum service-life policy is currently defined in terms of both vehicle age and vehicle miles. But, what about vehicle hours? As noted above, vehicle miles generally provide a better measure of vehicle ware as compared to vehicle age. However, the number of hours of service can vary significantly between vehicles with the same life-to-date mileage. Consider the contrasting cases of vehicles operated in slower moving, central business district routes versus vehicles operated for higher-speed, longer-distance commuter bus service. A vehicle operated at a relatively slow operating speeds will have many more service hours (and likely poorer physical condition) than a similar vehicles with the same life-to-date miles but operated at higher speeds. This suggests that vehicle hours should be included along with age and mileage as a minimum useful-life measure.

The problem with adopting vehicle hours as a measure of useful life is the fact that, unlike vehicle age and mileage, which can be measured (with mileage based on hub meter readings), operators do not currently maintain records of life-to-date vehicle hours and have no existing means of doing so. Hence, to be used as a measure of minimum useful life, these values would need to be *estimated* somehow, most likely based on an agencies average operating speed. The impact of average operating speeds (and by extension, vehicle hours) on vehicle retirement age is considered in the life-cycle cost analysis discussed in Chapter 8.

Project Approach

To meet the needs of the study, the study team completed the following six independent analyses. Each of these analyses aimed to provide a different perspective on (1) the current useful life of transit buses and vans, (2) the appropriateness of FTA's minimum life policy, and (3) the policy's impact on transit vehicle life expectancies and vehicle retirement decisions at the agency level.

- **Review of FTA Service-Life Categories:** The study provides descriptions of the types of vehicles found in each of FTA's five service-life categories. This includes descriptions of the vehicle physical characteristics, purchase costs, common service applications, primary manufacturers, and annual units sold. The analysis also considers the source markets for transit components including transit-specific and those components obtained from the broader heavy-truck and automotive markets. The market analysis is intended to provide perspective on transit's role and position within the broader truck and automotive market, with emphasis on where transit has the ability (or inability) to influence component and overall vehicle life expectancy.

- **Review of Useful-Life Related Bus Procurement Regulations:** The study reviews federal legislation and circulars to identify federal requirements potentially impacting either the useful life or vehicle retirement decisions of the nation's operators of transit buses and vans. This review includes FTA's bus testing regulations, the Americans with Disabilities Act (ADA), Buy America requirements, the Standard Bus Procurement Guidelines, and the Clean Air Act and its Amendments.
- **Review of Actual Retirement Ages:** NTD data were used to determine the actual ages at which U.S. agencies are currently retiring vehicles within each of FTA's service-life categories. This analysis was then used to compare the average retirement ages with the minimum FTA age requirements for each of these vehicle types to determine how the current minimum retirement ages may be impacting local operator's vehicle retirement decisions.
- **Industry Outreach:** The study team conducted two sets of interviews with bus fleet managers, vehicle engineers, maintenance staff, and procurement personnel from a sample of the nation's large, medium, and small-sized bus and van operators. The first set of interviews were designed to document the industry's concerns with FTA's current service-life policy to obtain agency perspective on how that policy impacts agency procurement decisions, retirement decisions, or the expected life of agency vehicles, and to elicit suggestions on how or if that policy should be changed. These interviews were also used to further document vehicle retirement ages (both agency policy as well as the actual retirement ages) and to obtain bus and van life-cycle cost data. The second set of interviews consisted of follow-up questions to the original interviews—with greater focus on specific engineering issues such as the impact of new vehicle designs and technologies on expected vehicle life.
- **Engineering Analysis:** The engineering analysis examines the life expectancy of transit buses and vans within each of the existing vehicle categories, all from an engineering perspective (i.e., based on ability to maintain, service reliability, and safety). This analysis is completed both from the perspective of individual vehicle components and from that of the vehicle as a whole (i.e., the factors that determine overall vehicle useful life). The analysis then considers the appropriateness of the minimum life requirements for each vehicle category given the useful-life characteristics of each vehicle's component parts.
- **Economic Analysis:** This analysis identifies that point in the life cycle of each bus and van type at which total life-cycle costs are minimized. This point provides a financially logical age (or mileage) at which to retire that vehicle. The identified minimum cost replacement ages are then placed in context with the results of the engineering analysis. The combination of these two perspectives helps illustrate factors that drive grantees' vehicle retirement decisions.

Once again, each of these analyses provides perspective on how the current FTA minimum life requirements compare with useful life as determined from actual vehicle retirement ages, agency assessments of useful life, and life-cycle cost analyses. In turn, these perspectives provide a vantage point from which to assess the merits of FTA's current retirement minimums.

CHAPTER 2. FTA SERVICE-LIFE CATEGORIES

This chapter provides a detailed review of each of the five service-life vehicle categories currently used by FTA. The purposes of this chapter are threefold. First, the chapter provides the reader with a solid understanding of the characteristics of each of the five vehicle types. This includes both the general physical differences between vehicles in the differing category types as well as differences in cost. This background is critical for an effective understanding of the findings in the sections and chapters to follow.

Second, the detailed descriptions of each vehicle type and the components used in their manufacture also serve to emphasize the commonalities among vehicles in the same category and differences between vehicles in different categories. Stated differently, this review of the five categories and the vehicles in those categories demonstrate that FTA is well served by the five existing minimum service-life categories. The exceptions are the 4-year and 5-year categories, which have significant similarities to each other in terms of both general characteristics as well as the names of the manufacturers serving those markets.

Third, this chapter provides a market assessment, for both vehicles and their components, of all five FTA bus and van categories. A primary objective here is to highlight the small size of the market for transit buses and vans relative to the auto and heavy-truck market from which most transit bus vehicle components and some bus and van vehicle types are derived. Given this small market share, the transit industry has little ability to impact the useful life of most transit vehicle types and components *in a cost-effective manner*. For this reason, the useful-life characteristics of transit buses and vans are largely determined by the wider truck and auto market, and any significant attempts to increase or decrease the useful life of transit specific vehicles are also likely to have a negative impact on vehicle cost.

This chapter is organized as follows:

- Service-Life Category Descriptions
  - Physical Description of Each Vehicle Type
  - Market Analysis of Vehicle Chassis and Components by Category
- Implications for the Current Service-Life Categories

Service-Life Category Descriptions

Large, Heavy-Duty Buses (12 Years; 500,000 Miles)

Approximately three in four rubber-tired transit vehicles are 12-year buses, making this vehicle type the transit industry’s primary workhorse. With a standard length of 40 feet (with variants ranging from 30 to 60 feet), a gross vehicle weight of roughly 33,000 to 40,000 pounds, and an average seating capacity for about 40 passengers, the 12-year bus is also the largest, heaviest, and biggest capacity rubber-tired vehicle serving the transit market.

Construction: Vehicles in the 12-year category are typically built on integrated structure chassis, unit body monocoque, or semi-monocoque chassis. Heavy duty chassis of the high-floor unit body type are built with substantial amounts of metal in under-structural bulkheads and sidewalls, located at points of concentrated stress such as the front and rear suspension attach points, passenger door openings, and the engine cradle. The size and thickness of these bulkheads and sidewalls results in a strong structure with a good margin for corrosion-related structural degradation and are a key factor in the overall longevity of this vehicle type.

Composite Monocoque Structure

A less expensive type of construction is an integrated chassis composed of multiple tubing elements, sometimes referred to as a “stick built” chassis. These stick-built structures consist of an integrated floor, roof, and sidewall structure of metal tubes welded together on which the major components are attached. Low-floor buses typically use this type of construction as there is very little space under the floor for large structural elements. The relatively small size of the structural elements of the low-floor bus provides less structure to bear the suspension and engine loads and reduces the tolerance of the structure to the effects of corrosion—a factor which may lead to shorted vehicle life expectancies for this vehicle type (this issue is discussed further in Chapter 6). Both traditional and stick-built structures are covered with outer panels composed of either stainless steel, aluminum or composite materials.

Low-Floor Stick Chassis

12-Year Vehicle Types

High and Low Floor Vehicles: Prior to the mid-1990s, all 12-year buses were exclusively “high-floor” vehicles. However, in response to the ADA, the industry developed low-floor buses that use ramps, kneeling mechanisms, or steps just a few inches above the curb or level with the curb for ease of entry. Low-floor buses are available in every size of heavy-duty bus from short lengths to 60-foot articulated vehicles. While the cost and most physical characteristics of high- and low-floor vehicles are similar, some operators suspect that low-floor vehicles may have a lower expected life as compared to the traditional high-floor vehicle. Chapter 6: Engineering Analysis addresses this possibility.

NABI Articulated Low-Floor Bus

Vehicle Lengths: 12-year buses come in a variety of sizes ranging from 30 feet to 60 feet (articulated) buses. Shorter 30- to 35-foot models are used on lower ridership routes and/or on streets with limited maneuverability. In contrast, 60-foot, articulated buses are used on high ridership corridors. Articulated buses are available in both high- and low-floor configurations.

Propulsion System Options: Twelve-year vehicles are available with a wide variety of propulsion system options including diesel, gas, CNG, electric, and hybrid systems.

Vehicle Costs: Table 2-1 presents typical purchase costs for large, heavy-duty, 12-year buses.

Table 2-1
Purchase Costs: Large Heavy-Duty Buses (12-Year)

Model Type	Cost
High-floor, 40 foot	$350,000
Low-floor, 40 foot	$350,000
40-foot Hybrid	$500,000
60-foot articulated	$500,000
Bus rapid transit	$500,000-$1M

12-Year Vehicle Market

Unlike all other bus and van types, the “12-year” bus is manufactured almost exclusively for the transit market by a small number of specialized manufacturers. Hence, while this vehicle includes numerous components obtained from the heavy-truck market, the chassis, body, and many key components of this vehicle type are manufactured specifically with the needs of the transit market in mind. Of the roughly 3,000 heavy-duty, 12-year transit buses sold each year, approximately 95 percent or more of these vehicles are destined for use in the transit market. Most of the remaining vehicles are sold for applications similar to transit, including shuttle buses at airport parking lots and at some national parks.

While 12-year vehicles are manufactured specifically for transit and similar applications, a large proportion of these vehicles’ components, including the engine, transmission, axels, brakes, suspension, air compressors, and power steering, are derived from the significantly larger heavy-truck market. In fact, the total value of components derived from the heavy-truck market account for roughly 40 percent of the value of a new 40-foot bus. In a sense, transit bus manufacturers “borrow” these components from the much larger heavy-truck market (roughly 300,000 heavy trucks are sold annually versus 3,000 twelve-year buses), leading to significantly cheaper component prices than would be possible if they were manufactured solely for the 12-year vehicle market. On the down side, these components are designed with the heavy-truck market in mind—and not the specific needs of transit users. Hence, transit has little ability to influence the useful-life characteristics of these components *in a cost-effective manner* (i.e., as any transit “customized” components would be developed for a transit market that is one percent of the size of the truck market for which those components are currently manufactured).

In contrast, the chassis, body and several other components, including the doors, wheelchair lifts, axles on low-floor buses, destination signs, and HVAC, are manufactured solely for the transit market. **Table 2-2** summarizes the shares of 12-year vehicles and related vehicle components destined for the transit market.

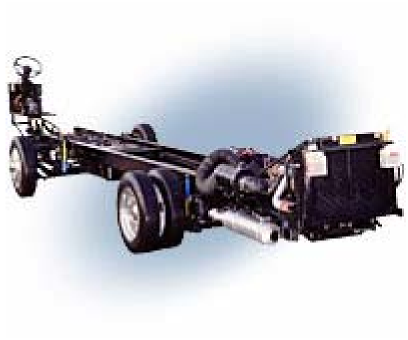
Manufacturers: Vehicles in this category are built by a relatively small number of manufacturers that specialize in this vehicle type. These include Gillig, Millennium Transit, North American Bus Industries (NABI), New Flyer, Nova Bus, and Orion.

Table 2-2
Market Analysis: 12-Year Bus Vehicles and Components

Vehicle Components	Primary Market	Annual Units Sold	12-Year Vehicle Share of Market	Share of Vehicle Purchase Cost
Total Vehicle				
12-Year Bus	Transit	3,000	95% or more	NA
Vehicle Components				
Chassis, body, doors, wheelchair lifts, low floor axles, destination signs, HVAC	Transit	3,000	95% or more	60%
Engine, transmission, axles, brakes, suspension, air compressors, and power steering	Heavy Truck	300,000	1%	40%

Small, Heavy-Duty Buses (10 Years; 350,000 Miles)

The 10-year service-life category represents the second-most durable buses used in transit. Vehicles in the category average roughly 30 to 40 feet in length (with most in the 30-foot range), have gross vehicle weights of approximately 26,000 to 33,000 pounds, and have seating capacity for between 26 to 35 passengers. Vehicles in this category account for roughly one percent of the nation’s bus and van fleet.



Construction: This class of vehicles was initially served by body-on-frame manufacturers using construction methods similar to school buses. These manufacturers build their vehicles using medium heavy-duty, rear engine, “stripped” chassis also used for both school buses and motor homes. Many of these buses are built using stripped chassis manufactured by medium- and heavy-duty truck manufacturers (e.g., International, Freightliner, and GM), although some 10-year vehicle manufacturers produce their own chassis. The 10-year transit vehicle manufacturer (e.g., Blue Bird, Optima, and Thomas Built) then adds a body and other components to complete construction of the 10-year bus.

More recently, small bus manufacturers have been adapting European designs for the North American bus market. The European designs have narrower widths (some as narrow as 96 inches) than typical North American bus designs and are promoted as more maneuverable in tight urban and suburban operating areas. The adapted European designs also incorporate aluminum integral structure unit body monocoque or semi-monocoque structures, which is a departure from the typical steel or stainless steel in more traditional North American designs. The vehicles are available in both low floor and high floor.

Champion Heavy-Duty Small Bus

Eldorado Heavy-Duty Small Bus

Vehicle Costs: **Table 2-3** presents typical purchase costs for small, heavy duty, 10-year buses.

Table 2-3
Purchase Costs: Small, Heavy Duty Buses (10-Year)

Model Type	Cost
Body on Frame (30-40 feet)	$200,000 - $250,000
Integral Chassis (30-40 feet)	$250,000 - $325,000

10-Year Vehicle Market

Transit buses account for only a very small proportion of the body-on-frame vehicle market from which the 10-year bus is derived. More accurately, of the roughly 60,000 vehicles manufactured using body-on-frame construction each year, only 200 to 300 are finished as 10-year transit buses (i.e., the body is a passenger compartment intended for transit or similar applications). The vast majority are finished as school buses or motor homes (in fact, many buses sold in the 10-year category are just modified school buses). Hence, for most 10-year transit buses, the primary transit-specific components are the body (including the interior), destination signs, and fare collection equipment. The majority of the vehicle's major components, including the chassis, engine, transmission, axles, brakes, and steering, are derived from either the broader school bus or motor home market of the still larger heavy-truck market. **Table 2-4** presents a summary market analysis of the 10-year vehicles and their components.

Manufacturers: Vehicles in this category are built by a relatively small number of firms that generally specialize in the manufacture of school buses, motor homes, and small transit vehicles. These include Blue Bird Corporation, Optima Bus, Supreme Corporation, and Thomas Built buses.

Table 2-4
Market Analysis: 10-Year Bus Vehicles and Components

Vehicle Components	Primary Market	Annual Units Sold	10-Year Vehicle Share of Market	Share of Vehicle Purchase Cost
Total Vehicle				
10-Year Bus	Transit	200 to 300	95% or more	NA
Vehicle Components				
Body, doors, destination signs	Transit	200 to 300	95% or more	35%
Chassis, wheelchair lifts, HVAC	School bus and motor home	60,000	Less than 1%	25%
Engine, transmission, axles, brakes, suspension, air compressors, and power steering	Heavy-Truck	300,000	Less than 1%	40%

Medium-Duty and Purpose-Built Buses (7 Years; 200,000 Miles)

Medium-Duty Cab Chassis

The 7-year service-life category represents the mid-level in terms of bus durability and size. Vehicles in the category average roughly 25 to 35 feet in length (with most in the 30-foot range); have gross vehicle weights of approximately 16,000 to 26,000 pounds; and have seating capacity for between 22 to 30 passengers. Vehicles in the 7-year category account for just over two percent of the nation’s bus and van fleet.

The majority of buses in this category are purpose built using either a front-engine cab chassis or a stripped chassis, both of which are manufactured by medium- and heavy-duty truck manufacturers (e.g., International, Freightliner, and Workhorse). A “final stage” transit vehicle manufacturer (e.g., Champion, Eldorado National, and Goshen Coach) then adds a body and other components to complete construction of the 7-year bus.

Purpose-Built Front-Engine Cab

Medium-Duty Cab Chassis Bus: Cab chassis is a term the trucking industry uses to describe a chassis equipped with a complete operator cab. The chassis has a conventional layout with an engine and transmission at the front, and the chassis is available in varying wheelbases and lengths. The cab chassis and chassis are sent incomplete to final stage manufacturers who mount custom bodies to the chassis rails. These chassis are popular and used for school buses, delivery trucks, transit and shuttle buses, and recreational vehicles.

Medium-Duty Stripped Chassis

Medium-Duty Stripped Chassis: Stripped chassis are similar to cab chassis except that the chassis is supplied without a sheet metal cab. The chassis is provided by the final stage manufacturer (e.g., a transit vehicle manufacturer) with an operator’s platform that includes the instrument cluster and switch gear, control pedals, operator heating and air conditioning, and an operator's seat. The final stage manufacturer then builds a single body to place on top of the chassis that houses both the passenger section and operator station. The stripped chassis enables a bus manufacturer to design a body configuration closer to that of an urban transit bus. The front engine layout, however, dictates the locations of the entrance door to be behind the front axle and operator station. Typically, the body is equipped with a single door. Front-engine chassis are popular because they are produced in large numbers for the trucking industry, and hence, are relatively affordable. However, the front-engine configuration compromises ride quality because of its heavily forward-biased weight distribution.

Vehicle Costs: Table 2-5 presents typical purchase costs for medium-duty, 7-year buses.

Table 2-5
Purchase Costs: Medium-Duty Buses (7-Year)

Model Types	Cost
Bus built on cab chassis	$75,000
Bus built on stripped chassis	$100,000
Trolleybus built on stripped chassis	$175,000

7-Year Vehicle Market

As with the 10-year vehicle type, vehicles in the 7-year category account for only a very small proportion of the medium-duty truck market from which they are derived. Of the roughly 50,000 vehicles manufactured by the medium-duty truck market each year, only about 300 are finished as 7-year transit buses (i.e., the body is a passenger compartment intended for transit or similar applications). The remaining vehicles of this general type are completed for a broad array of different uses including airport and hotel courtesy vehicles, ambulances, moving vans, medium-size trucks, and motor homes. Here again, for most 7-year transit buses, the primary transit specific components are the body (including the interior), doors, destination signs, and fare collection equipment. The remaining major components, including the chassis, engine, transmission, axles, and brakes, are once again derived from a broader, "non-transit" market. **Table 2-6** presents a summary market analysis of the 10-year vehicles and their components.

Manufacturers: The number of manufacturers that have developed transit vehicles in this category is larger than the 10-year and 12-year vehicle types. These include Cable Car Classics, Champion Bus, Eldorado National, Glaval Bus, Goshen Coach, Molly Corporation, Starcraft Automotive Corporation, Startrans, Supreme Corp, and Trolley Enterprises.

Table 2-6
Market Analysis: 7-Year Bus Vehicles and Components

Vehicle Components	Primary Markets	Annual Units Sold	10-Year Vehicle Share of Market	Share of Vehicle Purchase Cost
Total Vehicle				
7-Year Bus	Transit	300	90% or more	Na
Vehicle Components				
Body, doors, destination signs, wheelchair lifts	Transit	300	90% or more	30%
Chassis, engine, transmission, axels, brakes, suspension, air compressors, and power steering, HVAC	Medium-Duty Truck Market	50,000	Less than 1%	70%

Light-Duty Vehicles (5 Years; 150,000 Miles and 4 Years; 100,000 Miles)

The 4- and 5-year service-life categories represent the smallest buses used in transit, and are typically built on cutaway van chassis or modified vans approximately 16 to 28 feet in length as characterized by FTA. The majority of buses in this category are modified minivans, modified and unmodified full-size passenger vans, and specially built buses using cutaway chassis produced by automobile manufacturers. In contrast to the 12-, 10-, and 7-year categories (which are more clearly defined from one another), the 4- and 5-year vehicle categories have a significant amount of overlap with each other in terms of both the vehicle characteristics and the manufacturers that serve these categories. For this reason, these two categories are presented together in this section. Together, the two categories account for more than 20 percent of all transit buses and vans (the vast majority of which are 4-year vehicles).

Automotive Minivan with Second-Stage Access Ramp

Modified Minivans (4-year vehicle): The automotive minivan is a popular choice in serving vanpools and paratransit operations for transit authorities. These minivans are the same vehicles popular with large families because of their efficient use of space, low floor, and sliding doors. For use in the transit industry, minivans are often modified by second-stage manufacturers and equipped with wheelchair ramps and raised roofs. Installing a wheelchair ramp requires major modifications to provide sufficient height clearance for the wheelchair and its occupant.

Automotive Minivan with Second-Stage Raised Roof and Ramp

Modifications typically involve cutting and removing the floor structure between the front and rear axles and welding a custom floor constructed from rectangular tubes that is lower by as much as six inches from the existing structure. The modified floor necessitates rerouting of the exhaust system, brake lines, and electrical harnesses. While lowering the floor is an extensive modification, it enables the use of a ramp rather than a wheelchair lift. Another approach to integrating a wheelchair ramp into a minivan is to raise the roof and add a raised top. This modification increases the height of the opening, enabling the wheelchair and its passenger to enter the van without restriction. In performing this modification, critical structure, such as the point where the pillars and the roof structure come together, are retained. Other than these noted access enhancements, these vans are used as they are sold to the general market, with no further modifications.

Full-Size Passenger Vans (4-year vehicle): With the advent of the minivan, full-size vans have become less popular with large families, but remain popular in commercial applications and in serving vanpool and paratransit operations for transit authorities. Since 1996, all full-size vans use body-on-frame construction, meaning that the body is a separate component and physically mounts to the frame with bolts and rubber isolating bushings similar to the method used for trucks. Modifications to full-size vans are limited to raised roofs and the installed wheelchair lifts. These types of modifications are typically supported by the van manufacturer.

Full-Size Van Modifications

Buses Built on Cutaway Van Chassis (4- or 5-year vehicle): Cutaway chassis is a term the vehicle industry uses to describe a full-size van with the section of the body behind the B-pillar or the area aft of the front passenger seats removed. These chassis are manufactured primarily by the domestic auto manufacturers, including Ford, GM, and DaimlerChrysler. Final-stage manufacturers take these cab chassis, mount specialty-built bodies to the frame rails, and integrate them with the remaining front cab section. In doing so, final-stage manufacturers provide custom-made bodies that better meet the requirements of their customers or targeted industry (e.g., transit). For transit, bodies are constructed from a variety of materials including steel, aluminum, and fiberglass.

Cutawav Van Chassis

Note here that the distinction between the 4- and 5-year vehicles is not well defined. A general rule in making the distinction between them is that the 5-year vehicles generally feature higher capacity truck axles with dual rear wheels (versus single for the 4-year vehicle), higher capacity springs and other suspension components, a somewhat heavier-duty frame, and frequently a slightly wider body. These differences support high passenger capacities and some additional durability as compared to the 4-year models.

Example Passenger Body

Van and cutaway van chassis manufacturers provide detailed guidelines on approved modifications to their products. Following these guidelines prevents the final-stage manufacturer from having to re-certify to federal emissions and safety standards.

Vehicle Costs: **Table 2-7** presents typical purchase costs for light-duty, 4- and 5-year buses.

Table 2-7
Purchase Costs: Light-Duty Buses (4-Year and 5-Year)

Model Types	Cost
Modified Mini-Van (paratransit)	$30,000-40,000
– mini-van platform	$20,000-30,000
Full-Size Van (van pool)	$25,000-30,000
Small Bus Built on Cutaway Van Chassis	$50,000-65,000
– Cutaway van chassis	$20,000-30,000

4-Year and 5-Year Vehicle Market

More so than any of the other vehicle categories, transit has very little influence on the design and manufacture of vehicles in these two categories. For example, of the 1.1 million minivans sold each year, roughly 3,000 are purchased and modified for transit uses (less than 0.3 percent of the total market). Similarly, of the 370,000 cutaway chassis sold annually, roughly 2,500 are purchased and modified for transit uses (a 0.7-percent market share).

Manufacturers: Ford Motor Company, General Motors, and DaimlerChrysler are the three manufacturers building, selling vans, and supplying vans and cutaway van chassis to second-stage manufacturers for final assembly for the transit industry. The manufacturers modifying these vehicles for transit uses are largely the same as that for the 7-year vehicle category. These include Braun Corporation, Champion Bus, Eldorado National, Girardin Corporation, Goshen Coach, Mid Bus, National Coach Corp, Starcraft Automotive Corporation, Supreme Corp, Turtle Top, and Vision Point Mobility.

Implications for the Current Service-Life Categories

In addition to providing the reader with some familiarity of the five current service-life categories, the preceding review also supports some critical assessments of FTA's existing service-life policy and the broader issue of useful life in general. These include the following questions:

- Do the existing service-life categories "make sense?"
- Should FTA restrict the service-life categories in which vehicles are tested?
- What leverage does the transit industry have in influencing vehicle useful life?
- Do the service-life categories require periodic review?

The following sections address each of these questions.

Do the existing service-life categories “make sense?”

A key objective of this study was to review and assess the appropriateness of the five existing service-life categories—not just from the viewpoint of the useful-life values themselves (e.g., 12-, 10-, and 7-years), but also examining whether the groupings of vehicles in these categories “make sense.” Based on the review above, it is clear that the five existing service-life categories do represent logical groupings of vehicles having broadly similar characteristics in terms of construction methods, size, weight, passenger capacities, cost, and manufacturers (the following chapters address the actual useful-life similarities of vehicles in these five categories). **Table 2-8** provides support for this view.

Table 2-8
Comparison of Vehicle Types in FTA’s Five Service-life categories

Category	Typical Characteristics				Minimum Life (Whichever comes first)	
	Length	Approx. GVW	Seats	Average Cost	Years	Miles
Heavy-Duty Large Bus	35 to 48 ft and 60 ft artic.	33,000 to 40,000	27 to 40	$325,000 to over $600,000	12	500,000
Heavy-Duty Small Bus	30 ft	26,000 to 33,000	26 to 35	$200,000 to $325,000	10	350,000
Medium-Duty and Purpose-Built Bus	30 ft	16,000 to 26,000	22 to 30	$75,000 to $175,000	7	200,000
Light-Duty Mid-Sized Bus	20 to 30 ft	10,000 to 16,000	16 to 25	$50,000 to $65,000	5	150,000
Light-Duty Small Bus, Cutaways, and Modified Van	16 to 28 ft	6,000 to 14,000	8 to 22	$30,000 to $40,000	4	100,000

As noted in the text above, the key exceptions to this observation are the 4-year and 5-year vehicles built using cutaway chassis. Here, there is a significant degree of overlap between the 4- and 5-year vehicle categories in terms of construction type, sizes, vehicle weights, costs, and manufacturers. It should also be noted that the useful life attributes of these two vehicle types were not found to be significantly different in the review of actual vehicle retirement ages presented in the next chapter. However, despite these similarities, the review in this chapter and the analysis in succeeding chapters do not provide adequate grounds for combining these two into a single 4- or 5-year vehicle category.

Should FTA restrict the service-life categories in which vehicles are tested?

The preceding section suggests that FTA is well served by the five, existing, minimum service-life categories. However, this suggestion is subject to the important caveat that the bus testing program “rates” vehicles in the categories best suited to those vehicle’s characteristics. In recent years, some manufacturers have successfully lobbied in a more durable category than would appear warranted by their vehicle’s general characteristics (e.g., testing a bus with 10-year characteristics as a 12-year bus). This has resulted in service reliability issues and, in some instances, early retirement for the purchasing agencies when the tested vehicles were not found to have the expected durability.

The next chapter further discusses the overall requirements of the bus testing program and its relationships to useful life. The issue here is that while the category definitions appear sound based on this review of vehicle types, the most significant limitation in the current five-category system may lie in permitting vehicles to be tested in a higher service-life category than the one that best suits the characteristics of their vehicle. Given this consideration, FTA may wish to more tightly control in which categories vehicles are eligible to test based on some combination of characteristics (e.g., gross vehicle weight, seating capacity, other), but with the potential for special waivers to test in a different category so as not to stifle innovation. (Manufacturers should be required to provide reasonable justification as to why their vehicles should be tested in the higher durability category.)

What leverage does the transit industry have in influencing vehicle useful life?

The analysis above identified the origin markets for the chassis, body, and other components for each of the five vehicle categories. A key objective of this analysis was to demonstrate that nearly half of the vehicle components for 12-year buses and a significant majority of the components for all other vehicle categories (including chassis, engines, and transmissions) are obtained from the heavy-truck and automotive markets. Given that transit represents a very small proportion of these markets (generally less than one percent), the transit industry has little ability to influence the characteristics of these components, including their useful life, in a cost-effective manner.

A key exception here is the structure of 12-year buses. As discussed in Chapter 6, the useful life of a 12-year vehicle is determined primarily by the durability of its structure (as most major components are replaced or rebuilt over the life of the structure). To the extent that 12-year bus structures are designed and manufactured solely for transit use, the transit industry has better ability to influence this component’s design and durability characteristics. (Although, given the manufacturers’ small annual order sizes and local agencies’ tight capital budgets, funding such innovation is challenging in practice.)

With most other components and nearly all other service-life categories, this is not the case. Hence, for example, the transit industry cannot significantly alter the useful life characteristics of minivans or buses built on cutaway chassis without incurring the cost of further customizing these mass-produced items to meet transit-specific needs. In short, for component types and vehicle types derived largely from mass-produced markets, the industry is likely better served by adopting useful life expectations to the existing characteristics of these assets rather than attempting to further modify them to better suit transit.

Do the service-life categories require periodic review?

Finally, the useful life and other characteristics of transit buses and vans do change over time with changes in technologies, vehicle designs, new propulsion technologies, new materials, etc. Given this ongoing change, the current five-category system may no longer effectively capture the useful life or other characteristics of the nation’s bus fleets (e.g., consider the possibility of more durable BRT vehicles with useful life characteristics closer to rail vehicles). Thus, FTA should consider conducting periodic reviews of the service-life categories every 5 to 10 years.

CHAPTER 3. LEGISLATION AND PROCUREMENT

This chapter provides a review of legislative requirements, other than the minimum service-life requirements themselves, with emphasis on their potential useful-life implications. This includes FTA's bus testing regulations and ADA, Buy America, and Clean Air Act requirements. In addition, the chapter considers the impacts of procurement methods and guidelines on useful life expectations. Finally, this chapter reviews prior FTA and industry studies on both the establishment and the consequences of FTA's existing minimum service-life policy.

FTA Service-Life Circulars and Regulations

This section highlights the federal regulations that are relevant to the useful life of buses and vans (with the exception of the minimum life requirements themselves). While many of these regulations are found to have potential useful life implications, the implications generally are considered minor relative to the issues of annual mileage, new vehicle designs, changing life-cycle economics, and other drivers of useful life as considered elsewhere in this report.

Buy America Regulation

Buy America requires that rolling stock (i.e., vans, buses, and rail cars) procured with federal funding must contain, at a minimum, 60-percent domestic content by cost and that final assembly takes place in the Unites States. These requirements are designed to protect and ensure the long-term viability of the domestic bus and van market.

This legislation is also suspected of having a negative impact on vehicle life expectancy. Since bus manufacturers rely on the cost of major components (e.g., engine, transmission, and axles) to meet domestic content requirements, the Buy America regulation in effect limits the amount of money a bus manufacturer can spend on the (foreign built) structure of the vehicle, which tends to drive the vehicle's useful service life.

For example, North American Bus Industries (NABI) recently pulled the "CompoBus" from the U.S. market. This bus used an expensive and durable composite material for the vehicle's structure, which performed extremely well at FTA's Altoona testing facility. Unfortunately for NABI, the higher cost of the structure prevented it from complying with the Buy America regulation and from staying price competitive in the U.S. low-bid, bus procurement market. Manufacturing this composite structure in the Unites States was not considered an option given higher domestic production costs. The resulting bus structure cost exceeded the comparable cost level of the standard steel structure cost, making the CompoBus uncompetitive in a low-bid procurement environment.

Bus Testing Regulation

The Bus Testing Regulation requires new bus and van models to be tested at FTA's Altoona, Pennsylvania, test facility before they can be purchased using federal funds. The purpose of the testing is to provide vehicle performance information that grantees can use to help inform their purchase or lease decisions for new vehicles. These tests do not assign pass or fail standards, nor do they assign an overall vehicle performance grade. Rather, the testing process is only designed to report test results to the manufacturer and potential grantees. The Altoona program consists of seven automotive tests including maintainability, reliability, safety, performance, structural integrity, fuel economy, and noise.

Importantly, the bus's performance on the structural integrity test is believed to correlate closely with the bus's structural performance in revenue-generating service. This accelerated testing simulates up to 25 percent of the mileage accumulated by transit buses in revenue service. Most bus manufacturers design their structures to minimize the failures that occur during testing. Even the better manufacturers find themselves altering their designs based on testing results. The impact of this testing on actual vehicle useful-life remains unclear. It is certainly the case that manufacturers may beef up their structures to ensure that they pass the 25-percent accumulated mileage test. On the other hand, by designing their structures to minimize the specific types of failures that occur during testing, manufacturers may not be fully addressing the long-term structural requirements to meet FTA's minimum life requirements.

The Bus Testing Program may also have other useful life implications. The tests performed by the program vary depending on the FTA's service-life categories, with the tests becoming more stringent for vehicles with higher service-life minimums (e.g., testing is more stringent for a 12-year bus than for a 10-year bus, and so on). Over time, many manufacturers have lobbied to have their vehicles tested in a higher service-life category than might otherwise be expected given the characteristics of their vehicle (e.g., based on gross vehicle weight, passenger capacity, or length). Given the absence of a pass/fail or vehicle grading scale, this allows a manufacturer to advertise that their vehicle has been tested as a "12-year" bus when its design characteristics are really more similar to those of a typical 10-year vehicle. While this vehicle may easily pass the 25-percent accumulated mileage test for a 12-year vehicle, the structure may not withstand a full 12 years of hard revenue service. In this case, the Bus Testing Program may not impact useful life so much as potentially allow vehicles to be incorrectly classified.

Americans with Disabilities Act (ADA)

The ADA requires that transit buses and vans are accessible to persons with disabilities. Initially, this requirement was fulfilled with lifts, but more recently, low-floor buses have become the preferred approach to fulfill the ADA requirements. With the popularity of heavy-duty, low-floor buses, issues surrounding compliance with regulations such as maintaining wheelchair lifts are losing relevance on 12-year vehicles. However, buses in the lower service-life categories (e.g., 4-, 5-, 7-, and 10-year) that are built on top of truck or school bus-based frame rail chasses continue to necessitate the use of wheelchair lifts. This adds costs that have some effect on the economic measure of useful life. A more important effect of this regulation is that low-floor buses may not have the same long-term structural integrity as more traditional bus designs. This suspicion (voiced by some study interviewees) cannot be fully confirmed until more vehicles with this relatively new bus design approach and pass their useful life standards.

Environmental Protection Agency (EPA), California Air Research Board (CARB), and Clean Air Act

The EPA, CARB, and Clean Air Act Amendments affect the permissible emissions levels for buses and vans. In general, these regulations have little or no impact on the physical life expectancy of transit buses. This is because emissions regulations only have implications for vehicle drive trains (i.e., engine and transmission), and these vehicle components generally have life expectancies much less than that of the vehicle structure (e.g., 250,000 and 300,000 miles for the engine and more than 5000,000 for the structure). However, to the extent that environmental regulations drive the costs of replacement engines and transmissions, they can affect vehicle life-cycle economics (both nonrecurring capital costs and recurring operating and maintenance costs) and thus impact the “optimal” timing of vehicle replacement.

Major changes to the emission regulations are occurring in calendar years 2007 and 2010. The 2007 emission standards will dictate the use of exhaust after-treatment technology such as diesel particulate filters (DPFs). Most of the 2007 diesel engines will also incorporate cooled exhaust gas recalculating (EGR) technology. These technologies are available, and impacts on service-life options are not expected.

Procurement Methods and Guidelines

This section considers the impacts of procurement guidelines and different procurement methods on the life expectancy of transit buses and vans.

Standard Bus Procurement Guidelines

In the mid-1970s, FTA sponsored the development of standard bus procurement guidelines. This document is commonly referred to as the “White Book” (in reference to the color of its cover). Since then, the American Public Transportation Association (APTA) has sponsored updates of the bus procurement guidelines and expanded them to cover new technologies such as low floors, CNG, and articulated buses. The guidelines heavily influence the design and durability of heavy-duty transit buses. The guidelines address all areas of the vehicle including component design, performance, materials, corrosion protection, structural integrity, and warranties. By establishing useful and well-followed industry standards, this reference has indirectly helped to maintain bus and van useful life characteristics.

A group of the larger transit agencies in the Northeast has developed a more extensive set of bus specifications to append to the APTA “White Book.” These specifications have been developed to procure buses that can operate more reliably in the more difficult duty cycle and operating environment of these urbanized areas. The revised requirements are focused on more stringent structural integrity and corrosion prevention specifications. These are the most important constraints to fulfilling the FTA minimum service-life policy in these operating environments and even extending these buses to as long as 15 years of service. Examples include:

- The Washington Metropolitan Area Transit Authority (WMATA) uses these extended specifications to procure buses that can better fulfill the 15-year life objective established by its board policy.

- New York City Transit (NYCT), the main initiator of the more extensive bus specifications, was looking for a bus design that could achieve the 12-year service-life objective with reliable service in a slow-speed, stop/start urban duty cycle in New York City.
- The Toronto Transit Commission (TTC) was part of this research and is now trying to extend its bus useful life to 18 years or longer to help address constraints on bus replacement funding.

All three of these examples present different paths to the same priority—a structurally stronger bus to provide a longer and/or more durable service life in tough urban operating environments.

Third-Party Contracting Requirements

The methods transit authorities use to procure buses have potential impacts on their useful life. In particular, use of the low-bid procurement method without establishing some critical pre-bid requirements can result in the purchase of a lower quality bus, with a below-average life expectancy. This is the result of fierce price competition (and cost reductions) to ensure a contract win. Within a pre-bid environment, the firm establishment of structural component requirements during the specifications stage is of particular importance to ensuring the minimum life requirements are attained. All other bus components can be replaced as long as the main structure can continue service.

Conclusions: Impact of Regulations and Procurement Practices

In conclusion, while many federal regulations and industry procurement practices are believed to have potential useful life implications, these implications are generally considered minor relative to the issues of annual mileage, new vehicle designs, changing life-cycle economics, and other drivers of useful life. The key exception here is the low-bid procurement process, which may yield vehicles with lower quality structures leading to reduced vehicle longevity. To protect against this outcome, agencies need to establish firm structural component requirements during the pre-bid stage to ensure the minimum life requirements are attained.

CHAPTER 4. AVERAGE RETIREMENT AGES

This chapter uses NTD data to identity the actual retirement ages for vehicles from each of the five existing bus and van service-life categories. The analysis is then used to evaluate how closely these *average* retirement ages correspond to the FTA *minimums* for each category. To a certain extent, the observed difference between the observed distribution of actual retirement ages as compared to FTA's retirement minimums provides a measure of actual vehicle durability relative to the minimum retirement points. However, for many operators, the difference between the FTA minimum and actual agency retirement age is also a reflection of agency funding limitations (i.e., some agencies would retire their vehicles sooner if sufficient funding were available).

Analysis of Actual Fleet Retirement Ages Using NTD Vehicle Data

All U.S. transit operators receiving FTA Section 5307 Formula Funds are required to include a comprehensive listing of their transit bus and van fleet holdings as part of their annual NTD submissions. These vehicle listings document the number of active vehicles, age (date built), current year mileage, life-to-date mileage, make, model, fuel type, length, and passenger capacity of each sub-fleet operated by the reporting agencies (including vehicles operated directly by the agency as well as those operated by contract providers). Unlike the study survey data described in the next chapter (which only covers a small sample of the nation's bus and van operators), NTD provides good quality, empirical data on the actual retirement practices of virtually all U.S. bus and van operators[1].

Conspicuously missing from this data (from the viewpoint of this study) is documentation of the service-life category to which each sub-fleet vehicle has been assigned (i.e., 12-year, 10-year, 7-year, 5-year, and 4-year), a limitation FTA may wish to address in future revisions to the NTD reporting requirements. To a limited extent, these useful life assignments can be inferred based on the vehicle size and carrying capacity data found in NTD. In addition, the make and model data recorded in NTD can also be compared to that found in FTA's bus testing records to help supply the proper assignments (although NTD's make and model data are not always populated or use the same designations as the bus testing records). Both of these approaches have been used by this study to help document actual vehicle retirement practices for each minimum service-life category.

Analysis of NTD Bus and Van Data

This study used NTD transit bus and van vehicle data to assess the extent to which agencies operate vehicles beyond FTA's minimum service-life requirements and the extent to which the minimum vehicle age acts as a constraint on the fleet retirement decisions of the nation's transit

---

[1] *As of 2006, rural transit operators receiving FTA Section 5311 funds are also required to report on their bus and van vehicle holdings. These data are not expected to be published until later in 2007. With the exceptions of Urban 5309 operators (who own more than 95 percent of the nation's bus fleets) and Rural 5311 operators, no other operator types are required to report to NTD.*

operators. This analysis provides the measure of *average* vehicle useful life identified in Table 1-3 in Chapter 1.

In conducting this analysis, this study used the bus size classification employed by NTD prior to 2002 (at which time, the pre-existing, three-tiered bus size categorization based on seating capacity was consolidated into a single “Motorbus” category). This bus size classification provided a useful means to help segment bus vehicles into the five vehicle type categorizations as recognized by FTA’s service-life policy. In addition, the vehicle model names, manufacturer names, and vehicle specifications as reported to NTD were thoroughly reviewed to ensure that all bus and van models were placed in the correct minimum service-life categories (using each vehicle model’s Altoona bus test assignment). Vehicles that could not be definitively placed within one of these five categories were not included in this analysis. The resulting data sample covers all years from 1995 through 2001 and included more than 500 transit operators.

While NTD records the date built, make, and model of each agency’s sub-fleets, it does not record the actual retirement of these vehicles. Therefore, as a means of identifying when individual agency sub-fleets were retired, the records for each sub-fleet were tracked from year to year (i.e., across multiple years of NTD submissions). This analysis then identified the point in time at which individual bus sub-fleets “disappeared” from the NTD record (i.e., the age at which sub-fleets were retired from service). These data were then aggregated across all operators and time periods to estimate the average actual retirement ages for each vehicle type. Use of multiple years of NTD vehicle data was crucial to an accurate determination of these retirement ages. However, even with seven years of NTD data and over 500 different transit operators, the sample sizes for the 10-, 7-, and 5-year bus categories remain relatively small. Hence, the analytic results for these bus types are less certain in comparison to the considerably more popular 4- and 12-year vehicle types.

This analysis was used to identify the following for each vehicle category:

- **Actual Retirement Ages:** Specifically, the distribution of actual retirement ages and the average retirement age for each vehicle type (comparing two consecutive years of data to determine which vehicles were retired from one year to the next).
- **Percentage of Fleet Vehicles Exceeding the FTA Minimum and Later Age Values:** Given the problematic nature of comparing vehicle records across multiple years of NTD submissions, the analysis also looked at the percent of active fleet that:
    - Exceed the service-life minimum by one or more years
    - Exceed the service-life minimum by two or more years
    - Exceed the service-life minimum by three or more years and so on…

  This analysis is very helpful in assessing the distribution of fleet vehicle exceeding the minimum retirement ages.
- **Impact of the Minimum Service Requirement:** The impact that the minimum service requirement has on the actual distribution of retirement ages.

Analysis of 12-Year/500,000-Mile Vehicles

As noted earlier, 12-year category vehicles account for more than three in four of the nation's 90,000 transit buses and vans. NTD data on vehicles in the 12-year/500,000-mile category show that retirements peak at ages 14 through 17, and the average retirement age for vehicles in this category is 15.1 years (see **Figure 4-1**). Hence, the vast majority of these buses are retired well beyond the 12-year and 500,000-mile minimum. For example, more than three-quarters of retirements occur at age 14 or later. In contrast, only 6 percent of vehicles are retired at age 12 and only 7 percent at age 13. These results clearly indicate that the 12-year minimum itself is not a binding constraint for most transit operators, since they operate buses well beyond this age.

Figure 4-1: Retirement Age Distribution of 12-year/500,000-mile vehicles

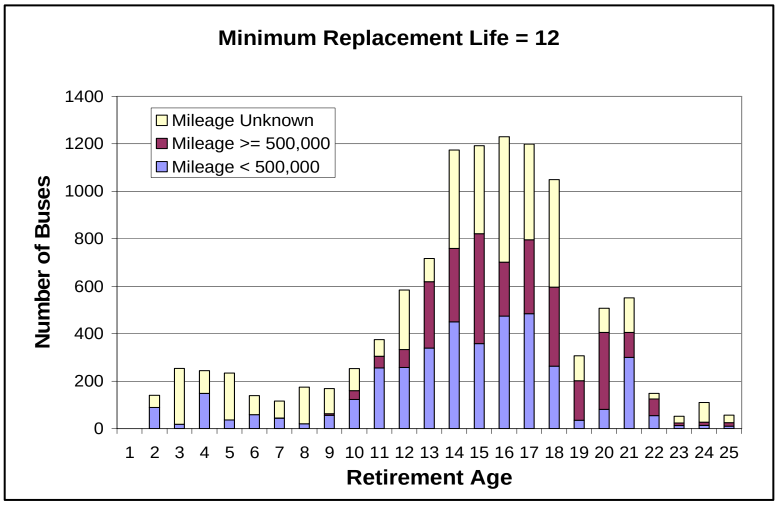


Figure 4-1 also suggests that some vehicles are retired prior to the 12-year minimum. Many of these retirements consist of vehicles that have reached the 500,000 minimum mileage prior to the 12-year minimum age (the chart shows the vehicle life-to-date mileage as of the year prior to vehicle retirement). However, there are also a number of "false" retirements depicted in this chart that capture NTD data entry errors (or changes in reported vehicle names from one year to the next), and perhaps some vehicle trading between agencies. Vehicle retirements prior to age nine were excluded from the calculation of average retirement age.

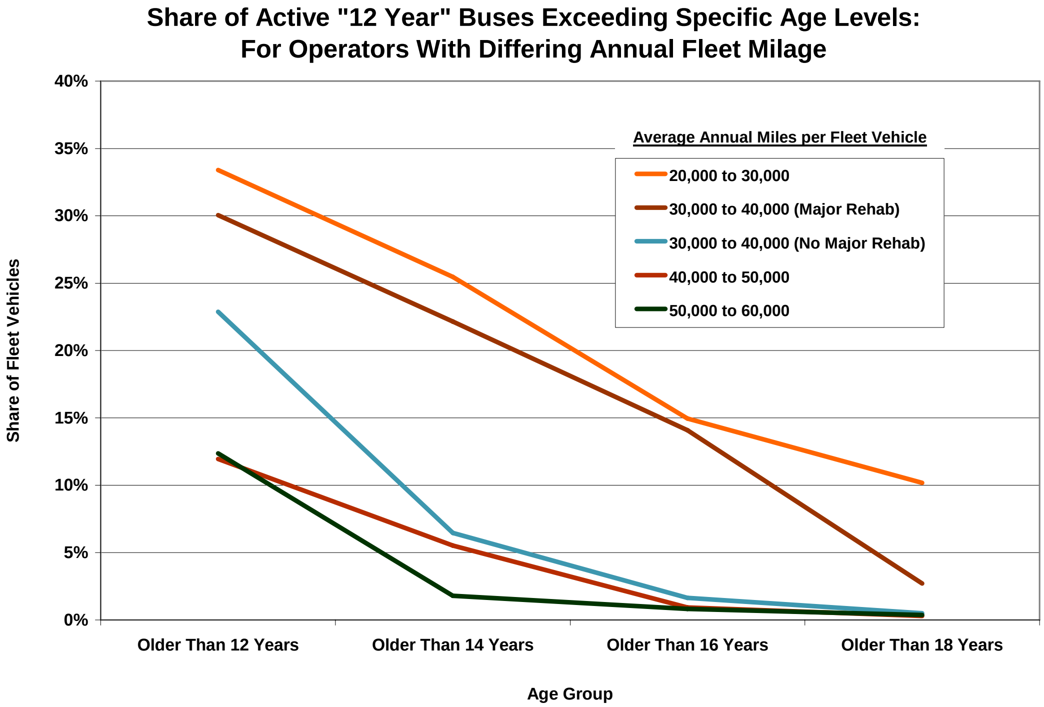
While the analysis in Figure 4-1 is helpful in evaluating the distribution of retirement ages, it has little to say about the impact of vehicle utilization on useful life. In contrast, **Figure 4-2** presents the proportion of active 12-year buses that are older than 12, 14, 16, and 18 years respectively (on the horizontal axis). These proportions are further segmented by average annual sub-fleet mileages, including groupings of vehicles with between 20,000 and 30,000 annual miles, 30,000 and 40,000 annual miles, and so on (with the 30,000 to 40,000 group further segmented between those agencies that do and do not perform comprehensive mid-life overhauls)[2]. As expected, the proportion of vehicles exceeding each age group threshold declines as the age threshold increases. Moreover, while roughly one-third of all vehicles for operators with between 20,000 and 30,000 annual miles per vehicle remain in service after the 12-year minimum is passed, a surprising 12 percent (roughly one in eight) of vehicles for operators with between 40,000 and 60,000 miles remains in service past age 12 (representing a range of between 480,000 and 720,000 life-to-date miles). ***Hence, even the highest mileage operators, some with vehicles well***

---

[2] *Note that most US transit operators do not perform a comprehensive mid-life vehicle overall for their 12-year buses. Moreover, those agencies that do perform such overhauls have average annual sub-fleet mileages of between 30,000 to 40,000 miles.*

beyond the 500,000-mile minimum, still maintain their vehicles in service past the 12-year age minimum.

Figure 4-2



While the proportion of fleet vehicles remaining in service declines for all annual mileage groups, Figure 4-2 shows that the proportions in service remain fairly high past the 12-, 14-, and 16-year age thresholds for vehicles that do versus those agencies that do not perform a major mid-life overall. These findings demonstrate the effectiveness (if not the cost effectiveness) of these rehabilitations in extending vehicle life.

Finally, Figure 4-3 repeats the analysis from Figure 4-2, but this time segmenting 12-year vehicles between the articulated (60-foot), standard 40-foot, and 35-foot vehicle types[3]. This chart demonstrates that while the proportion of vehicles in service past 12 years tends to decrease with increasing vehicle length, a significant proportion of the active vehicles for each of these vehicle types remain in service after 12 years (including one in four 35-foot vehicles, one in five 40-foot vehicles, and one in six articulated vehicles).

In summary, this analysis suggests that the current 12-year requirement provides a reasonable retirement age minimum for large, heavy-duty vehicle types. This is because the majority of these vehicles are retired in the 6-year period following the service-life minimum, with the *average* retirement age occurring roughly three years past the *minimum* (providing a cushion for the early retirement of poor reliability vehicles). Similarly, the fact that most of the vehicle retirements for this group are concentrated in a 5- to 6-year period following the retirement minimum implies that the vehicles have roughly common useful characteristics, providing some

---

[3] *Note: As of 2005, NTD does not report many 30-foot buses with ages of 12 years or more.*

validation to the current grouping of these vehicles within the same service-life category. Finally, regardless of annual vehicle mileage or vehicle length, a significant share of the nation's heavy-duty vehicles remains in service after the 12-year minimum and many with more than 14 years of service.

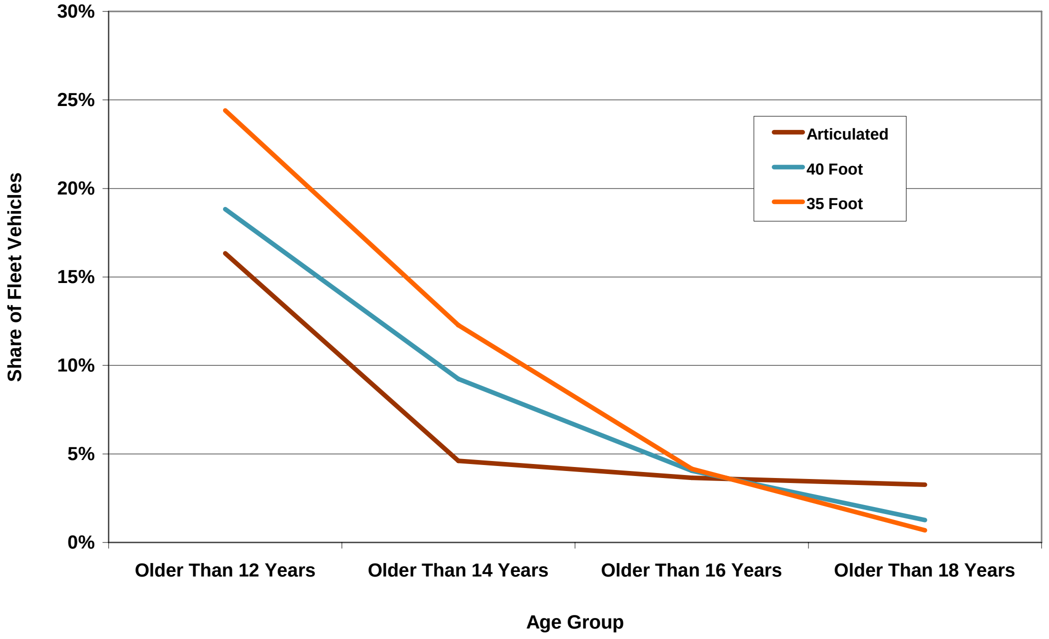
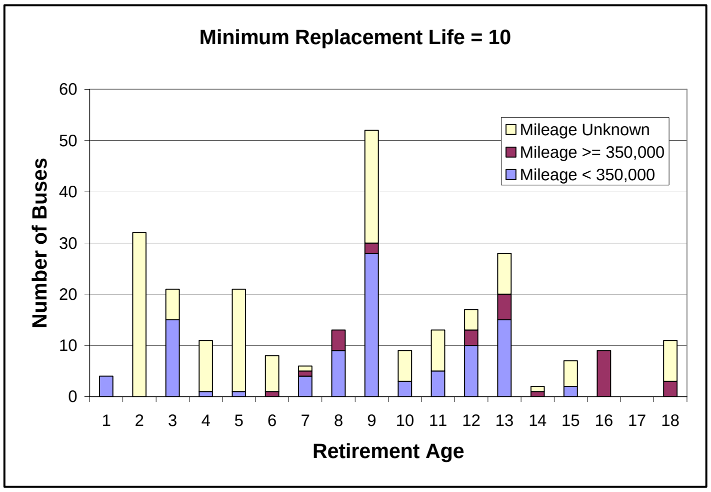


Figure 4-3

Share of Active "12 Year" Buses Exceeding Specific Age Levels: Articulated, 40 Foot, and 35 Foot Vehicles

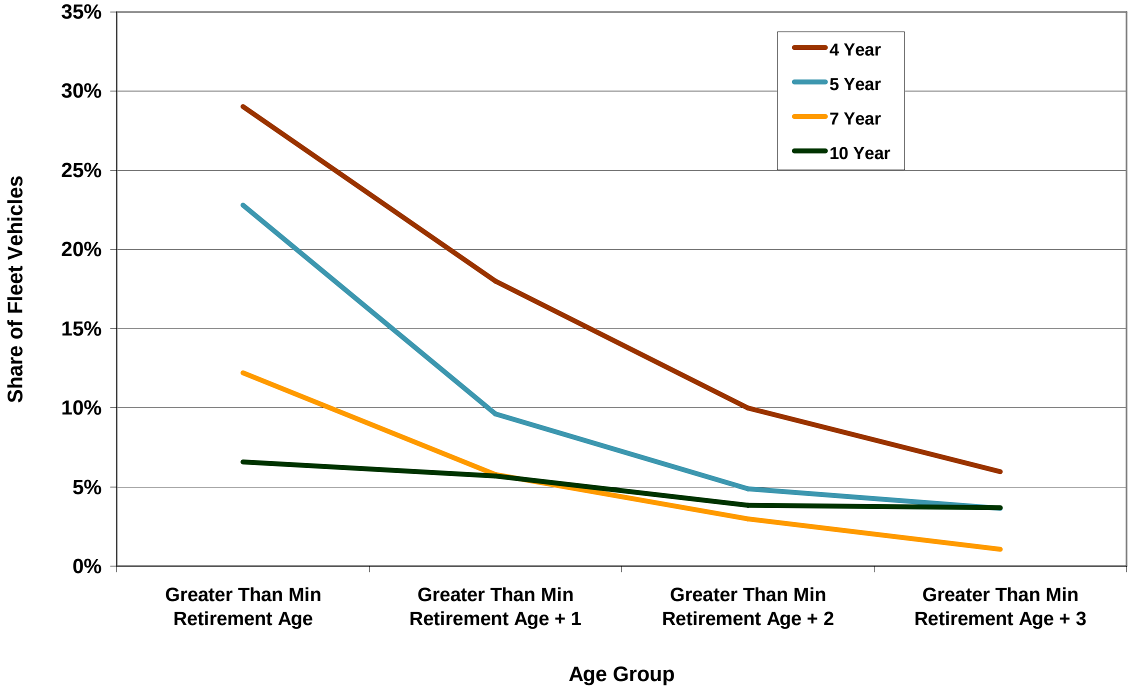
Analysis of 10-Year/350,000-Mile Vehicles

Figure 4-4: Retirement Age Distribution of 10-year/350,000-Mile Vehicles



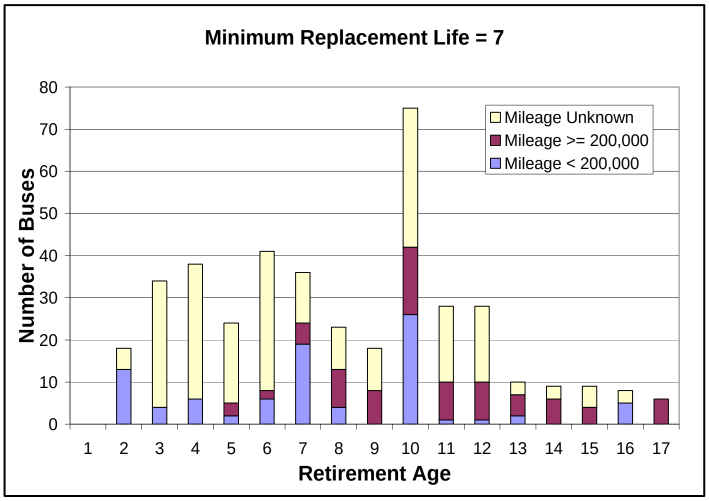
The number of 10-year vehicles reported to NTD is far smaller than the number of 12-year vehicles—these vehicles account for little more than one percent of the nation's transit buses and vans (roughly 1,000 active vehicles). Consequently, the analysis of average retirement age for this category suffers from small sample issues (**Figure 4-4**). This data suggests an average retirement age of approximately 8.4 years, which is obviously less than the minimum retirement age. Hence, the quality of the analysis for this vehicle category is clearly problematic (the study had difficulty in effectively identifying this vehicle type based on the data reported to NTD) and requires a better data source to properly evaluate an actual *average* retirement ages.

Figure 4-5
Share of Active Vehicles Exceeding Specific Age Levels:
For 4, 5, 7, and 10-Year Buses and Vans



NTD could be used, however, to document the proportion of 10-year vehicles currently in service that exceed the 10-year minimum in age (see **Figure 4-5**). This analysis suggests that only 7 percent (or roughly one in 15) of these vehicles remains in service past the 10-year service-life minimum. It is also clear from Figure 4-5, that the 10-year vehicle type has the *lowest* proportion of active vehicles exceeding the service-life minimum of the five existing service-life categories. This may suggest the need to reduce the minimum life requirement for this vehicle type by one or more years.

Figure 4-6: Retirement Age Distribution of 7-year/200,000-mile Vehicles



Analysis of 7-Year/200,000-Mile Vehicles

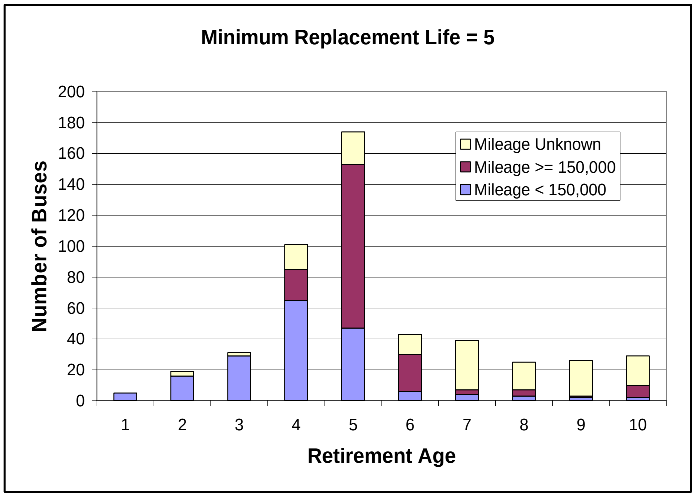
As with the 10-year vehicle category, the number of vehicles in the 7-year category is relatively small, accounting for just over 2 percent of the nation’s active bus and van fleets (under 2,000 vehicles). However, the data quality for this sample is believed to be superior to that for the 10-year category based on the review of the

NTD records, and points to an average retirement age of approximately 8.2 years, with retirements spiking at 10 years (**Figure 4-6**). This figure suggests that seven years is an appropriate *minimum* retirement age for these vehicles, as many operators are clearly able to keep vehicles past this age and are retiring their vehicles within roughly a three- to four-year period after the minimum requirement is satisfied. Figure 4-5 also supports this finding, with 12 percent (roughly one in eight) of the nation's active "7-year" vehicles having a current age of 8 years or more.

Analysis of 5-Year/150,000-Mile Vehicles

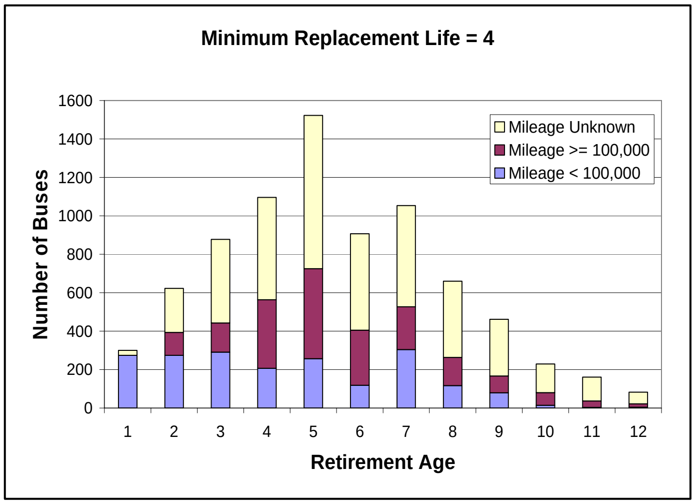
Vehicles in the 5-year age category also account for only a small proportion of the nation's bus and van fleet (about 1.4 percent of the total or about 1,500 active vehicles). For this vehicle type, the average retirement age was estimated to be 5.9 years (**Figure 4-7**). Most vehicles are maintained in operation up to and beyond the five-year minimum, although the age of retirements peaks right at five years with a significant number at four years (presumably for vehicles that attain the required mileage before they are retired). As with the analysis for 10- and 7-year categories, the 5-year vehicle analysis using NTD suffers from small sample issues, and this approach should be revisited at a future point in time using an improved NTD dataset.

Figure 4-7: Retirement Age Distribution of 5-year/150,000-mile Vehicles



Analysis of 4-Year/100,000-Mile Vehicles

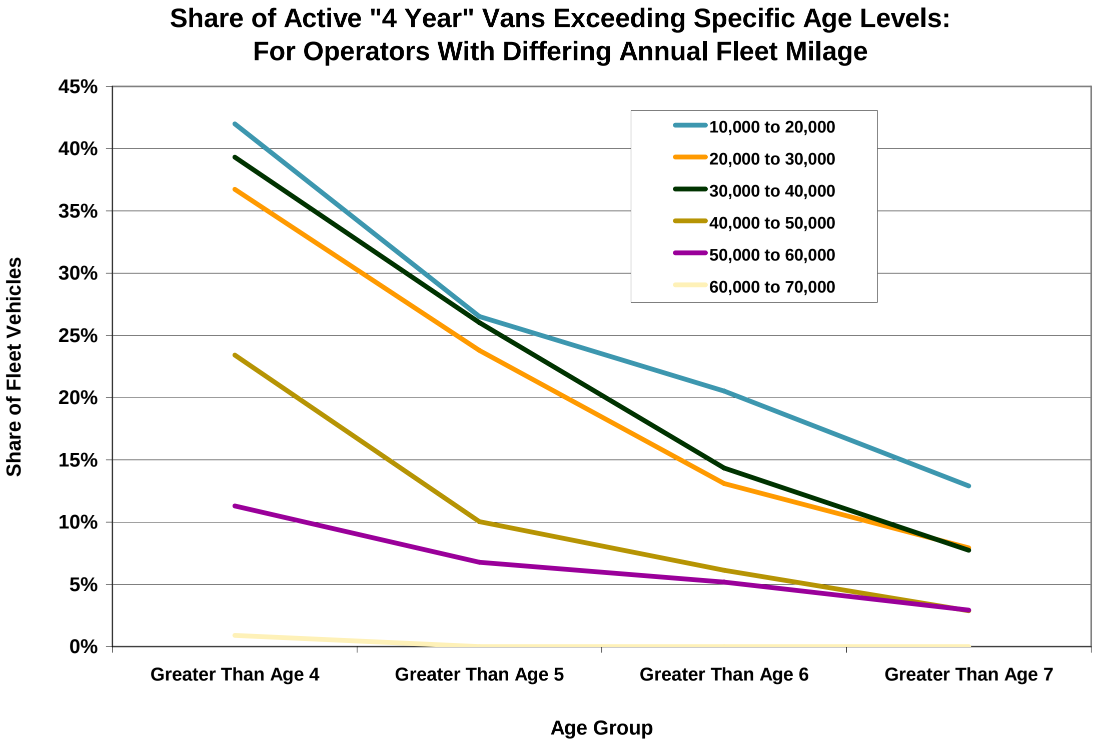
Figure 4-8: Retirement Age Distribution of 4-year/100,000-mile vehicles



Four-year vehicles account for close to one-fifth of the nation's total bus and van fleet, or roughly 15,000 active vehicles. The NTD data indicate that most vehicles in the 4-year and 100,000-mile category are retired between four and seven years of age. The majority of vehicles are being retired past 4 years, with the average retirement age around 5.6 years. This suggests that the four-year minimum service age for this vehicle category is appropriate for the characteristics of this vehicle type (**Figure 4-8**). The fact that most retirements occur after the minimum retirement age suggests that the current minimum is not binding for most operators (a desirable characteristic for a retirement *minimum*).

Similarly, Figure 4-9 presents the proportion of active 4-year vehicles exceeding the 4-year minimum age and other age thresholds for operators with differing annual mileages per feel vehicle. As with the similar chart presented above for the 12-year vehicle category, even those operators with very high annual mileage per fleet vehicle have more than one in 10 vehicles exceeding the minimum age requirement. On average, roughly one in three active 4-year vehicles is age five or older.

Figure 4-9



Summary

Table 4-1 summarizes the results of the preceding analysis. This analysis of NTD bus vehicle data demonstrates that the *average* retirement age for most bus and van types occurs *after* the minimum age requirement is met. This finding supports continued use of the existing policy as it provides age minimums that are clearly less than (but within one to three years of) the average actual retirement age. This analysis also suggests that vehicles retired prior to the current age minimum have satisfied the current mileage minimums. Finally, a significant number of vehicles are operated well beyond the minimum age requirement, suggesting that well-maintained vehicles can be retained in service well past the expected vehicle useful life.

The fact that most vehicles are retired one to three years after the minimum age requirement has been attained is not, in and of itself, proof that the "true" useful life values of these vehicle types is greater than the minimum life requirement. In some and perhaps many cases, the actual retirement age exceeds the minimum requirement due to funding constraints (i.e., many operators would replace their vehicles earlier given additional funding capacity) and not optimal or preferred retirement age considerations. However, that fact that so many vehicles are regularly operated well beyond the service-life minimum requirements clearly indicates that most vehicles types do have some useful service-life remaining well past the current FTA minimums.

Table 4-1
Minimum Versus Average Retirement Age by Vehicle Category

Vehicle Category / Minimum Retirement Age	Average Retirement Age (Years)	Share of Active Vehicles That Are:	
		One or more years past the retirement minimum	Three or more years past the retirement minimum
12-Year Bus	15.1	19%	9%
10-Year Bus*	8.4?	7%	4%
7-Year Bus	8.2	12%	3%
5-Year Bus / Van*	5.9?	23%	5%
4-Year Van	5.6	29%	10%

* Average retirement age estimates for this vehicle category suffer from small sample issues.

The fact that vehicles in service past the service-life minimums continue to deliver valuable service is demonstrated in Figure 4-10 (12-year buses) and Figure 4-11 (4-year vans). Both of these charts present the average annual mileage by vehicle age for *vehicles* in low, average, and high-mileage *fleets*. Both charts demonstrate that, while annual service mileage tends to decline with vehicle age, vehicles well past the minimum retirement age continue to see significant service miles. Hence, far from being delegated to support or special service vehicles, vehicles exceeding the minimum retirement age continue to deliver a significant proportion of the nation’s transit services.

Assessment of Existing Bus Type Categories Based on NTD Analysis

FTA’s current bus category definitions were designed to be widely encompassing and include virtually any new rubber-tired vehicle intended for transit service and purchased with FTA funds. In terms of actual vehicle characteristics (e.g., length, passenger capacity, GVW), the existing service-life categories show considerable variation in vehicle characteristics both between and within each category (e.g., 12-year buses range in length from 30 to 60 feet). The question then concerns how sensible these categories are based on the observed useful life experience of each category type.

Based on the preceding analysis, the 12-year vehicle type demonstrates the greatest consistency in vehicle retirement ages, followed next by the 4-year vehicle category (refer to the relatively smooth shape of the retirement age distributions in Figures 4-1 and 4-8 above). These orderly distributions around a mean replacement age are indicative of commonality of their overall useful life characteristics. In contrast, the distribution of retirement ages for the 10-, 7-, and 5-year vehicle types is more disorganized (see Figures 4-4, 4-6, and 4-7). While some of this disorganization is a function of the relatively small purchase quantities for these less popular vehicle categories, it may also reflect greater dissimilarities in the designs of these vehicle types (given their smaller purchase quantities, there is probably less industry impetus and opportunity for vehicle type standardization). Hence, based on this analysis of NTD data, the 12- and 4-year categories appear to "make sense," while the logic of the 10-, 7-, and 5-year categories may benefit from further review.

Figure 4-10

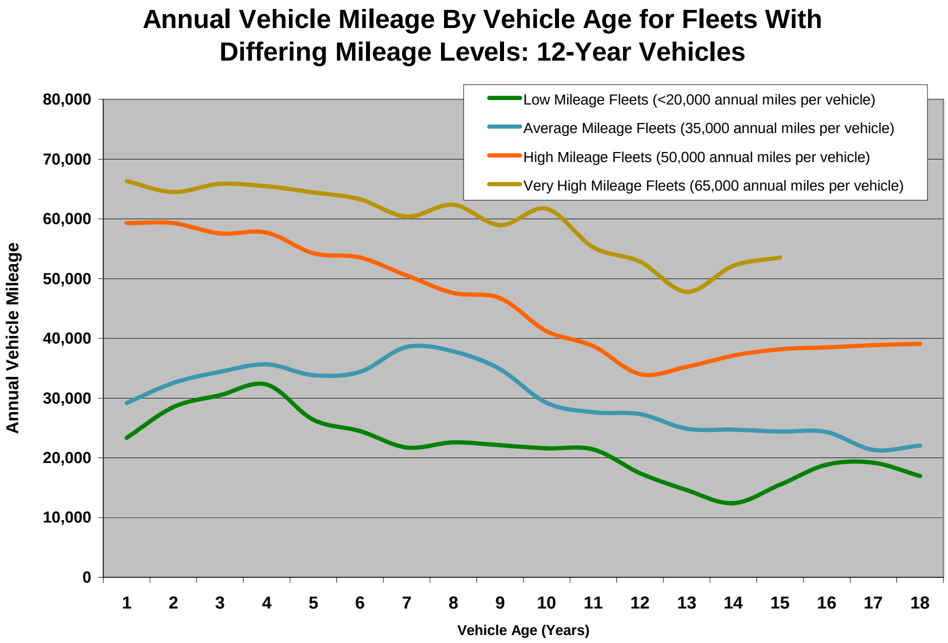
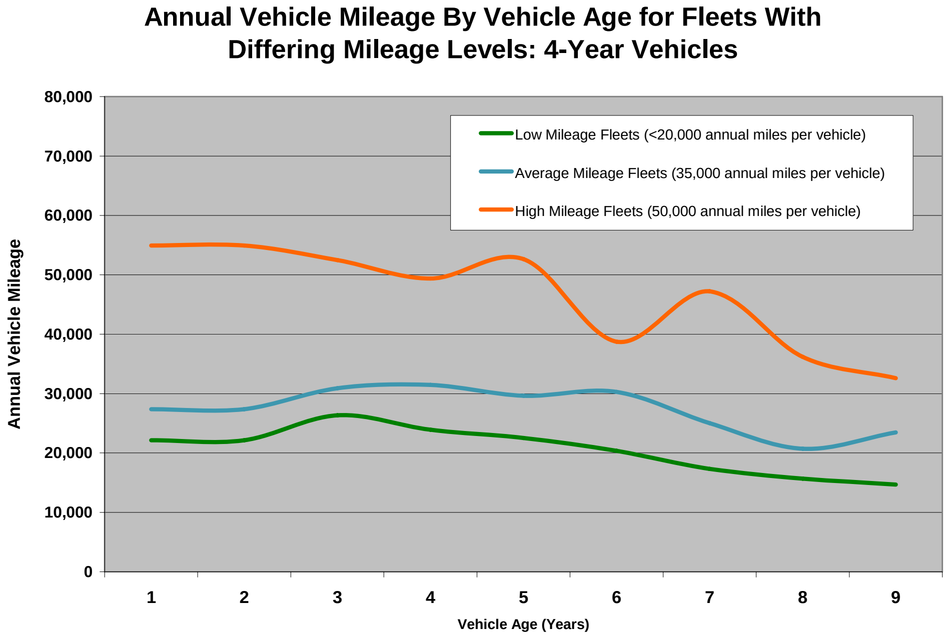


Figure 4-11



CHAPTER 5. INDUSTRY OUTREACH

This chapter presents the results of the first set of industry outreach interviews for this study (the results of the second set of interviews are presented in the next chapter). This first outreach effort consisted of a set of detailed interviews with a sample of transit agencies, vehicle manufacturers, transit industry suppliers, and private operators. The purpose of the interviews was to evaluate how FTA's existing minimum service-life requirements impact agency and manufacturer decisions regarding vehicle design, procurement, and retirement. The interviews were also designed to elicit industry responses to a range of potential changes to the existing service-life requirements and to obtain industry representatives' suggestions on how the current requirements might best be modified. Finally, the first set of industry outreach interviews provided valuable vehicle life-cycle cost data including the cost and expected useful lives of all major vehicle components (data required to support the life-cycle cost analysis in Chapter 7). Upon completion of these initial interviews, a second set of follow-up interviews was conducted to further investigate several issues identified in the original interviews. This second set of interviews focused on bus engineering concerns, and the results of these issues are considered in the next chapter.

Transit Agency Participants

The research team developed an interview guide to assess the current experience of transit agencies with the FTA service-life requirements. Questions covered areas such as vehicle replacement decisions, alternatives to the current FTA policies, maintenance practices, and the impacts on service quality. Responses to the transit agency interview guide were received from the nine transit agencies identified in **Table 5-1**.

The responding agencies include a mix of operator types such as urban, suburban, and rural operators and represents operators with fleet sizes ranging from less than 40 to over 4,000 vehicles. Seven of the nine agencies have purchased some or all of their fleet vehicles using FTA funds and hence have fleet vehicles that are subject to FTA's minimum service-life requirements. Three of the agencies that have purchased some but not all of their vehicles using federal funds (Montgomery County Ride-On, Frederick County TransIT, and Jefferson Transit) are subject to state-imposed minimum life requirements that are at least as stringent as FTA's). NYCT was included in the sample because of both its large size and its decision to use non-FTA funding sources as a means of having more control over vehicle testing. Toronto was included because of the absence of an active federal bus funding program in Canada (or service-life requirements) and the consequent need to regularly maintain heavy duty vehicles up to and past age 18.

Staff Interviewed

The staff interviewed for this study were all members of senior and mid-level management holding fleet management and fleet maintenance responsibilities. These respondents included representatives of one or more of the following types of positions within their organizations:

- Bus Operations Manager

- Chief Mechanical Officer
- General Manager (smaller agencies only)
- Superintendent of Engineering
- Equipment Maintenance Manager
- Director of Vehicle Maintenance.

Table 5-1
Agencies Responding to Detailed Interview Guide

Operator	Type	Fleet Size (2005 NTD)	Vehicles Purchased Using FTA Funds
Los Angeles County Metropolitan Transportation Authority (Metro), Los Angeles, CA	Major Urban	2,815 Buses	Most
Massachusetts Bay Transportation Authority (MBTA), Boston, MA	Major Urban	1,311 Buses 235 Vans	Yes
New York City Transit, New York, NY	Major Urban	630 Articulated Buses 4,024 Buses 655 Vans	No
Toronto Transit Commission (TTC), Toronto, Canada	Major Urban	1,508 Buses	No
Washington Metropolitan Area Transit Authority (WMATA), Washington, DC	Major Urban	1,467 Buses 378 Vans	Yes
Capital Metro, Austin, TX	Medium Urban	434 Buses 187 Vans	Yes
Ride-On - Montgomery County, MD	Suburban	341 Buses	Some
TransIT Services of Frederick County, Frederick, MD	Small Urban / Rural	55 Buses 8 Vans	Some
Jefferson Transit, Jefferson County, WA	Rural	20 Buses 17 Vans	Most

It is important to note here that most staff interviewed had considerable familiarity with the useful life of heavy-duty transit buses (i.e., the 12- and 10-year FTA bus categories), but generally did not have a firsthand understanding of the 4-, 5-, and 7-year vehicle types. This is in part due to the relative scarcity of the 5- and 7- year vehicle types and to the fact that these smaller vehicle types are typically operated and maintained by contract operators. The exceptions here are Frederick County TransIT and Jefferson County Transit, which both provided valuable insight on the smaller vehicle types.

Agency Interview Guide Responses

This section presents the received responses to the study interview guide by the nine responding agencies. Not all of the agencies responded to every question; therefore, the number of responding agencies is indicated for every question. **Appendix A** provides a complete summary of all responses to the interview guide.

Agency Useful-Life Experience

This section focuses on the sample agencies' current vehicle retirement policies, including their expected and scheduled replacement age by vehicle type and other criteria driving retirement, such as duty cycle, funding constraints, or maintenance issues.

Table 5-2 summarizes the planned and agency policy retirement ages for heavy-duty vehicles for each of the sample agencies. Table 5-2 also shows the range of actual retirement ages for recently retired fleet vehicles and a brief listing of some primary drivers of these recent retirement decisions.

Table 5-2
Planned and Recent Actual Retirement Ages: Heavy Duty Vehicles

Agency	Planned/Policy Retirement Age (Heavy-Duty Vehicles)	State Retirement Policy (if any)	Actual Retirement Experience	Issues With Recently Retired Vehicles
WMATA	15 years (imposed by WMATA Board)	No	15 to 16 years	High maintenance costs, reliability
TTC	18 years, at 40,000-45,000 annual miles	No	18 Years	High maintenance costs
Montgomery County	12 years	Yes, same as FTA for larger vehicles	Close to scheduled; TMCs retired at 15 years; Gilligs retired at 12 years	Any delays due to procurement requests or testing/approval; TMCs retired due to high maintenance costs; Gilligs retired because of no lift, poor quality, and high maintenance
New York City Transit	12 years	Yes, 7 years (for all bus types and sizes)	13-15 years; had to retire Grummans before FTA minimum	Overage due to lack of funding availability; Early retirement of Grummans due to heavy duty cycle
MBTA	12 years	No	Recent retirements at 16-19 years	Limited funding
Los Angeles Metro	13 years or 500,000 miles	No	Within 2 to 3 years of planned	Retirement beyond scheduled due to budget and legal consent degree obligations; Early retirement due to fire and/or beyond repair
Frederick	12 years	Yes, same as FTA for larger vehicles	Within 1-2 years of planned	Delay due to procurement requests

Agency	Planned/Policy Retirement Age (Heavy-Duty Vehicles)	State Retirement Policy (if any)	Actual Retirement Experience	Issues With Recently Retired Vehicles
Austin	12 years	Not stated	Within 1-2 years of planned; TMC CNG buses recently retired 6 months early – FTA approved	Outdated CNG equipment
Jefferson Transit	15 years	Yes, similar to FTA	15 to over 20 years	Physical condition, duty-cycle, maintenance requirements

There are two key observations to be noted in Table 5-2. First, all nine of the agencies reported having a policy on the useful life of heavy-duty buses, and four of these nine agencies have *planned* retirement ages that exceed the FTA minimum of 12 years (with Los Angeles Metro at 13 years, WMATA and Jefferson Transit at 15 years, and TTC at 18 years). Second, the *actual* vehicle retirement for all nine agencies typically occurs between one to four years after the FTA minimum has been reached (but can occur as late as vehicle age 20). Moreover, for seven of the nine agencies, the actual retirement age also typically exceeds the (less stringent) *planned* or policy retirement age. Given these observations, it is clear that FTA's current minimum service-life requirement for heavy-duty buses is not actively constraining the agencies' retirement decisions (as retirements occur after the minimum retirement age has been reached). Limited capital funding was cited as the primary reason why the timing of actual vehicle retirements has exceeded the planned/policy retirement age by all but one of the responding agencies. The lone agency, Frederick, stated that funding is not an issue, although the state rarely provides as many vehicles and/or funds as the agency has requested.

When asked to report on the primary problems associated with recently retired vehicles, the agencies cited issues relating to vehicle maintenance, deteriorated physical condition, and component and structural wear related to heavy duty-cycles. FTA's minimum service life requirements were only cited by three of the nine agencies (Boston, Los Angeles, and Austin), and each of these agencies typically maintains its vehicles two or more years past the current FTA minimum. New York ranked FTA requirements as the lowest priority, as it does not purchase vehicles with federal funds.

It is also important to note here that all but one of the agencies has had to retire vehicles prior to their planned retirement age and in one case prior to the FTA minimum (Austin retired a problem CNG vehicle prior to 12 years with FTA approval). The causes of earlier-than-planned retirements included problem vehicles with abnormally high maintenance costs, a desire for equipment upgrades, and damage beyond repair. Boston is the only agency that did not report early retirement of its vehicles. This is despite a tough operating environment and the frequent need to keep vehicles well beyond planned, 12-year retirement age. MBTA staff also stated their desire for an 8-year replacement cycle to eliminate the need for a mid-life overhaul and to maximize use of the latest bus industry technologies. None of the agencies reported having to take advantage of FTA's "like-kind exchange" provision, which permits early retirement of specific vehicles and assignment of the unamortized FTA interest in them to replacement vehicles.

Mid-Life Overhaul Practices

Table 5-3 summarizes responses to the current practices for comprehensive, “mid-life” overhauls of vehicles. This overhaul is applied to all of the agencies’ larger (40-foot), heavy-duty cycle vehicles, with the strategy of maintaining vehicles to meet or pass their scheduled retirement age. Overhauls are typically timed with the expected life of major components (e.g., drive train rebuilds), while service on minor components is on an as-needed basis. New York reported that mid-life overhauls are planned, though not typically performed on all vehicles. In this case, the vehicles are rehabbed on an as-needed basis or on an individual campaign basis, following a preventive maintenance strategy. Washington, DC, states that it is looking into additional smaller overhauls at 3, 9, and 12 years for other component replacements and upgrades. On the other hand, Toronto indicated that it is considering revising its current 6- and 12-year overhaul program to a program with a 9- to 10-year major overhaul and smaller component overhauls at other years, due to the decline in provincial funding.

Table 5-3
Mid-Life Overhaul Practices: Heavy-Duty Vehicles

Mid-Life Overhaul?	Number of Respondents	Agencies	Approximate Cost per Vehicle ($2006)	Additional Years Expected	Components
Yes	4	Washington, Toronto, New York	$110,000	3 years	Engine, transmissions, A/C, brakes and other major components
Yes	1	Boston	$175,000	6 years	
Sometimes	1	Los Angeles	Limited due to lack of manpower and funds		Not stated
No	4	Frederick, Montgomery, Jefferson	Not considered cost effective		

It is important to note that the sample presented here is heavily biased in favor of those agencies that do perform mid-life overhauls (with four of the nine respondent agencies performing such overhauls on a regular basis). Based on a prior FTA condition assessment of 43 U.S. transit bus fleets, the practice of completing major mid-life overhauls is relatively rare, with only seven of the assessed operators regularly performing a major rehabilitation (four of which are also included in the sample for this study). In contrast, those agencies that do not perform a scheduled mid-life overhaul typically complete many of the same rehab activities over the life of the bus, but on an as-needed basis (as opposed to a single, coordinated effort). It is important to note that those agencies undertaking major mid-life rehab activities represent many of the largest in the nation, and hence are of critical importance to this study.

Impact of FTA’s Minimum Service-Life Requirements

Although some agencies have occasionally had to either retire a vehicle prior to the FTA’s minimum age or lighten the duty of vehicles to reach these minimums, the overall sense is that agencies are not directly impacted by the current FTA requirements. This is because the agencies have a state or agency-imposed minimum retirement age, which is more stringent than the FTA minimums, and/or are impacted by the availability of capital funding, which forces them to keep vehicles longer than desired.

When asked how the agency has been impacted by FTA’s current minimum retirement ages, all but one of the agencies reported no impact due to having other state or agency-imposed minimums (Washington, Montgomery, Frederick, Jefferson) or not purchasing vehicles with FTA funds (Toronto and New York, and for some vehicles Los Angeles, Montgomery, Frederick, and Jefferson). Austin reported not being negatively impacted by FTA guidelines, although it has had to retire some buses six months early due to outdated equipment, which FTA approved. Boston reported being impacted by FTA minimums due to the need for a mid-life overhaul to reach the current 12-year, heavy-duty minimum.

Although New York reported no current impact from FTA’s policy, it has had to retire a group of vehicles prior to the FTA minimum retirement age, which consequently led to a change in its vehicle funding policy. These vehicles were purchased with federal funds, and thus, the agency had to reimburse 80 percent of the purchase price, which was taken from other projects. This early retirement forced a delay in future bus procurements and was the reason behind the current policy to purchase all vehicles with state and local funds.

In the absence of the FTA 12-year minimum retirement age, Boston would consider retiring vehicles earlier, at eight years, to eliminate the need and large capital expense of a six-year mid-life overhaul and keep up with the latest vehicle technologies. Toronto and Los Angeles reported interest in retiring vehicles earlier than their own self-imposed policies require, although in practice, this would not be possible due to funding constraints.

Regarding the appropriateness of the current FTA policy, four of the agencies (Montgomery, Frederick, Austin, and Jefferson) indicated that the retirement minimums are suitable and did not recommend any adjustments or revisions. It should be noted that these agencies did not report any major problems with vehicles and have retired vehicles close to their planned retirement age. Specific recommendations to the current FTA minimum retirement ages were given by five of the nine agencies. **Table 5-4** summarizes these recommendations. The main recommendations reported by various agencies are to include rehabilitation costs or extended warranties as reimbursable costs and to give the agency more options or discretion on retirement ages.

Table 5-4
Recommendations on Current FTA Policy

Agency	Recommendations
Washington – WMATA	• Include options for agencies • Include rehab costs and extended warranties as reimbursable costs (up to some % of original costs)
Toronto	• Shorter service-life options are not feasible (due to heavy-duty and procurement methods) • Increase to 12, 15, 18, 20 and 24 years at agency's option • Include rehab costs in federal funding
New York	• Provide options • Mileage looks high based on annual average • Include rebuild costs as reimbursable expense (to improve maintenance) • Include stipulations on FTA funds for rebuild • Use bus testing for bus prequalification • Consider shaker-table in bus testing • Identify higher-level options in "White Book" specs
Boston	• Reduce age/mileage from 12 years/500,000 miles to 8 years/300,000 miles
Los Angeles	• Age is acceptable; however, allow more discretion on vehicles not performing at optimum level

Vehicle Service-Life Categories

To review the current FTA service-life categories, the survey asked agencies for their opinion on alternative vehicle classes based on durability and procurement value. These alternatives are summarized as follows:

- More durable (more expensive) vehicles for high-volume service, with longer FTA minimum ages and mileage requirements
- Less durable (less expensive) vehicles, with shorter FTA minimum retirement ages and mileage requirements
- Use of the agency's own engineering and economic analysis to determine best retirement age and rely on existing funding constraints to ensure a reasonable length of service life
- Mix of durability and minimum age/mileage at the procurement level (procurement options).

Appendix A presents each agency's specific responses to each of these options. The following is a summary of those responses.

More Durable Vehicles: Six of the nine responding agencies stated they were not interested in a more durable vehicle (only two agencies expressed a clear interest in this possibility). This generally negative response reflected concerns relating to cost effectiveness, weight, rider comfort, and the slower adoption of new technologies. Some agencies state that a more durable vehicle type might be considered if its components were equally durable, especially with the strain from heavy-duty cycles—and thus, would not increase maintenance needs or decrease quality.

Less Durable Vehicles: Interest in less durable, less expensive vehicles was even lower, with all nine agencies expressing significant concerns. Some agencies stated these vehicles would not be appropriate for their duty cycles, and others expressed concern over the relationship with the expected life of components, a decrease in quality, and the increase in procurement efforts. An MBTA participant reiterated their interest in reducing the current FTA minimum for heavy-duty buses from 12 to 8 years.

Agency Determined Retirement Age: None of the agencies clearly objected to the alternative option of allowing agencies to use their own judgment in determining vehicle retirement ages (i.e., drop all minimum life requirements and rely on funding constraints to ensure vehicles are retained for reasonable service lives). Based on the current actual retirement ages of the nine responding agencies, few agency vehicles would be retired before FTA's current minimums (as is already the case for funding reasons). One concern with this option, as expressed by an NYCT participant, is the capability of some agencies to accurately determine the best vehicle retirement age.

Mix of Procurement Options: As a starting point for discussion, the interview participants were provided with the list of procurement options presented in **Table 5-5**, and were then asked to consider these options or provide similar ideas. The concept of providing a mix of procurement options was generally negative, with only three of the nine operators clearly interested in this possibility. Concerns included skepticism over the ability of vehicle manufacturers to develop cost-effective vehicles with the longer life spans and the slower adoption of new technologies with long-lived vehicles. Respondents were also concerned with the capacity of "rehab vendors" to meet increased demand and how rehab would be monitored and approved by FTA. There were also concerns as to how the smaller, medium, and even some larger sized operators would implement this option given that the vast majority of these operators do not currently perform (or have the capacity to perform) mid-life rehabilitations. In addition, operators with low average annual vehicle mileages often do not have the need to perform a mid-life overhaul given their relatively low rate of vehicle deterioration.

Allowing Earlier Retirement of the Existing Vehicle Types: The agencies also provided their opinions on permitting earlier retirement of the existing FTA vehicle types. Positive impacts stated include reductions in fuel and maintenance costs, reductions in emissions (newer vehicles), increased customer satisfaction from newer technologies, and reductions in average fleet age. It was also suggested that few agencies would be able to take advantage of such a reduction in service-life requirements due to funding constraints.

Extending Retirement of the Existing Vehicle Types: On the other hand, most of the agencies cited negative impacts from extending the current FTA minimum service life. These negative impacts include a decrease in quality of service (higher rate of failures, aesthetic of vehicles, reliability) and an increase in maintenance costs (between 10- to 50-percent higher). However, the agencies did not predict significant increase or decrease in emissions and energy efficiency.

Table 5-5
Potential Transit Bus and Van Procurement Options

Category	Length	Approx. GVW	Seated Passengers	Minimum Life		Rehabilitation *	
				Years	Miles	Years	% Comp
Heavy-Duty Articulated Bus	55 - 70 ft	38,000 -	48 - 60	12	500,000	6	30%
				15	650,000	6,10	50%
				18	750,000	6, 10, 15	75%
Heavy-Duty Large Bus	35 - 48 ft	33,000 - 40,000	27 - 40	10	450,000	5	20%
				12	500,000	6	30%
				15	650,000	6,10	50%
				18	750,000	6, 10, 15	75%
Heavy-Duty Small Bus	20 - 30 ft	26,000 - 33,000	20 - 35	8	300,000	4	10%
				10	350,000	5	20%
				12	400,000	6	30%
Medium-Duty and Purpose-Built Bus	20 - 30 ft	16,000 - 26,000	22 - 30	7	200,000	5	20%
				9	250,000	6	30%
Light-Duty Mid-Sized Bus	20 - 35 ft	10,000 - 16,000	16 - 25	5	100,000	4	10%
				7	150,000	5	20%
Light-Duty Small Bus, Cutaways, and Modified	16 - 28 ft	6,000 - 14,000	8 - 20	4	100,000	n/a	0%
				6	125,000	4	10%

* The rehabilitation columns define the potential years of the rehab to account for components that cannot achieve the extended life and the likely % of components that will need to be replaced during those rehabilitations.

Vehicle Components

The survey also asked respondent agencies about the life expectancy of individual bus and van components and how these expectancies affect the decision to retire and/or rebuild vehicles. Unfortunately, only three of the agencies responding to the survey provided detailed information on the life expectancy and costs of the requested list of vehicle components (see Appendix E). Given the small agency response rate, this data was appended with manufacturer responses and other industry data to help guide the life-cycle cost analysis in Chapter 7.

Cyclical Nature of Component Replacements: However, the data reported by those few agencies do clearly show that the expected life of major body components, such as the structure and panels, aligns closely with each agency's scheduled vehicle retirement age. Similarly, engine and transmissions have an expected life of approximately half or one-third of this retirement age, which is roughly in line with the responses on mid-life and other scheduled overhauls. When viewed in total, the timing and cost of major vehicle component replacements are such that component replacement costs peak in cycles throughout the life of the vehicle, with minor cost peaks occurring roughly every three years and major peaks every six years.[4] (The six-year peak corresponds closely to the drive train rebuild; see Figure 7-6 in Chapter 7). As discussed in more detail in Chapter 7, these cost cycles help to define the logical retirement points throughout a vehicle's life. Specifically, an operator will only perform a major, life-extending rehabilitation if the operator intends to operate the vehicle for an additional three to six years. Otherwise, the decision to undertake the life-extending rehab is not cost effective.

---

[4] *The actual timing depends on average fleet mileages, maintenance practices, duty-cycles and other factors.*

Component Determinants of Vehicle Useful Life: When asked to consider which components drive or define the useful life of the vehicle as a whole, several of the agencies identified the condition of structural members, including the impact of corrosion, as the key driver of total vehicle useful life. Two agencies (Frederick and Montgomery) stated that specific or individual components are not the direct drivers on vehicle retirement decisions, but the general conditions of the vehicle (maintainability, reliability of components, etc.). Boston reported its retirement decisions are age-based, and not component-based, and also stated that components are not expected to last beyond 12 years.

Besides structural members, other components listed as important to the vehicle replacement decision include the electrical system, suspension, exterior, and floors. Conversely, among the components listed as having no impact on retirement decisions include doors, brakes, windows, and wheel chair lifts.

Other Issues Impacting Useful Life

Survey respondents were also asked to consider issues suspected of having indirect impact on the useful life of buses and vans, such as procurement policies and other federal regulations.

Procurement Processes: The agencies were asked to report the procurement process typically used and any effects this process has on the expected useful life of vehicles. Most of the agencies reported using a best value, request-for-proposal process based on price and other factors. These agencies feel this process is better than low-bid as higher quality products are expected or can be negotiated.

The transit agencies interviewed universally agreed that using a low-bid procurement approach negatively affected the bus useful life. To mitigate this, some agencies have taken a much more rigorous approach to specifying bus structure life, requiring finite element analysis of the structure, shaker table tests, or strain gage testing in the agency’s operating environment. However, even those agencies that did not detail bus structure requirements acknowledged that it was important to state minimum bus life requirements in their specification. Agencies reported that low-bid procurements resulted in buses that were lower in quality and designed to just fulfill the minimum bus specifications used in that procurement. In the interviews, one agency noted that manufacturers have only two options to reduce their price—one is to use lower cost/lower quality components and the other is lower paid/less skilled labor in vehicle assembly. With all of the North American bus manufacturers struggling financially, agencies feel that manufacturers have adopted both approaches.

All agencies agreed that the bus structure is the key determinant of bus life. The other bus components and systems can be replaced as long as the main structure can continue in service. Negotiated procurements, instead of low bid, can benefit an agency and get additional features such as stainless steel that are advantageous in extending the life of the structure. However, those agencies that are using a best-value negotiated procurement approach are not doing so primarily to extend bus useful life. The main motivations for a negotiated procurement are to get the best mix of desirable features and highest reliability for the agency to reduce operating costs.

Buy America Regulations: Agencies were also asked if Buy America regulations have affected the quality and/or useful service life of vehicles. Two of the agencies who responded to this question stated that these requirements do in fact have an impact, specifically on how the limited market impedes the implementation of the latest design features or technologies. Boston reported that the reduction of minimum life of heavy-duty vehicles to eight years would assist in fulfilling this provision differently, while Austin reported that useful life is dependent on the procurement process of the agency. WMATA staff also noted that this regulation can limit/affect how a manufacturer develops structure (the largest component manufactured abroad and hence budget constrained to meet the Buy America requirements). Given that structure is typically the largest component ultimately defining the total useful life of the vehicle, a less expensive (lower quality) structure will result in a lower life expectancy vehicle. This regulation does not directly affect three of the agencies (Toronto, Frederick, and Montgomery), while responses were not received from the remaining agency (New York).

Bus Testing Program: Another indirect factor that may potentially affect the purchasing and retiring of vehicles is the Bus Testing Program conducted at Altoona, PA. Five of the respondent agencies reported using the bus testing results in the procurement process to establish performance requirements. This included reviewing the testing results in writing specifications, evaluating bids, and discussing purchases with vendors. However, these agencies recommended that the actual test results would provide the agencies with more information to evaluate vehicles in the procurement process. One respondent was fairly critical of the value of the testing program itself, suggesting that competition between vendors is a more effective (and less expensive) means of ensuring product quality and longevity.

“White Book” Procurement Guidelines: The survey also asked respondents about the influence of the “White Book” procurement guidelines on vehicle durability and expected service life. Five of the agencies agreed that the procurement guidelines should be adapted to include alternative service-life options to reflect differences in vehicle designs. One agency noted the importance of recognizing the difference in the strain applied to urban, heavy duty-cycle vehicles as compared to other service environments (10-year urban vs. 15-year suburban), while another agency reported using more arduous specifications in its procurement than those in the guidelines. The agencies were also asked whether they would consider the use of design specifications for a 10-year and a 15-year vehicle, if retirement at those ages were allowed by FTA policy. **Table 5-6** summarizes the responses to these questions.

Table 5-6 illustrates a split in whether agencies would consider the change in design specifications. As expected, those agencies that would find the 10-year bus design specification a positive change (Boston and Los Angeles) also have expressed difficulty in maintaining vehicles past the current 12-year minimum and support the shortening of minimum service life. These two agencies are characterized as heavy metropolitan areas, and as such, tend to be more severe on vehicles. In contrast, agencies that would consider the 15-year, and not the 10-year, design specifications (Washington and Toronto, which also have tough urban operating environments) already have policies in place to retire vehicles at that age and beyond.

Table 5-6
Design Specifications of 10- and 15-year bus

Vehicle Category	Number of Agencies	Notes
Would you consider the use of design specifications for a 10-year bus?		
Yes	2	If the bus components remained at 12-years Do not necessarily agree funding should be tied with age
No	2	Board policy does not allow lower minimum age
Maybe	1	
No answer provided	4	
Would you consider the use of design specifications for a 15-year bus?		
Yes	3	Already used by agency Work on specifications for longer-life bus needed
No	3	Too long, would not hold up in urban environment
No answer provided	3	

The respondents' lack of experience with lighter-duty vehicles limited the review of whether agencies would consider different service-life options for medium and light-duty buses and vans. Only two agencies responded to this survey question. Austin stated that the market for light-duty vehicles is as it should be, while Boston would like to see a change in service-life options for smaller vehicles. Jefferson County, one of the few respondents with a good understanding of light-duty vehicle characteristics, already uses more stringent retirement ages for the smaller vehicle types including a target retirement age of 9 for "7-year" vehicles, a target retirement age of 8 for "5-year" vehicles, and a target retirement age of 5 for "4-year" vehicles.

Used Bus Disposal: Under current regulations, operators are required to compensate the federal government if a transit bus is retired and sold prior to meeting the FTA retirement minimum. After that point in time, the operator can retire the vehicle and sell it either as a used vehicle or for scrap value. If the book value of a bus being sold is more than $5,000, then FTA requires the agency to reimburse them (in practice, the amount of the reimbursement is subtracted from the agencies next available FTA funding certification for the purchase of new buses).

Most agencies reported selling their used vehicles in bulk for their salvage value, with the sale price based on the quantity and the condition of the vehicles sold, and with scrap value ranging from roughly $3,000 to just $50 per bus. If the bus is in good shape upon retirement, agency maintenance staff will typically scavenge the functioning parts and the bus will be left in poor condition to be sold for less than $500. In some cases, the retired vehicles are sold either to other transit operators or to non-transit entities. Agencies indicated that these sale prices are typically in the low thousands. Regardless of how the vehicles are disposed, the funds obtained from bus sales or salvage represent only a small fraction of the original purchase price and the funds received from these sales are generally deposited in the agency's general fund (and hence not used specifically for the purchase of new vehicles). Agencies reported that, given the low dollar amounts involved, sale and salvage value funds do not play any role in agencies' vehicle retirement decisions.

Other Procurement Issues

The last section of the survey asked respondents to reiterate any difficulties in the procurement of vehicles and in maintaining them past their minimum service life. As previously reported, most agencies have had to retire vehicles prior to their scheduled retirement age. These vehicles were reported to have high maintenance costs, and the most common way to deal with them was to lighten their duty cycle, while two of the agencies reported retiring vehicles due to outdated components.

Interest in a "Lemon Law": Respondents were asked whether they would be interested in the creation of "lemon law" providing agencies with an opportunity to retire problem vehicles prior to meeting the service-life minimums without financial penalty. The question did not specify how that option would be structured or what standards would be applied in identifying a "lemon" vehicle. With the exception of New York, who did not respond to this question, all of the agencies agreed that a potential "Lemon Law" consideration within the FTA service-life policy is a very desirable option. However, the agencies expressed concern over the enforcement of such options, the performance measures used to justify early retirement (the suggestion was that these should be established based on a vehicle's performance industry-wide, not within a single agency), and the quality aspects from the manufacturers' and suppliers' side. **Table 5-7** summarizes the individual agencies' responses.

Table 5-7
Responses to Exceptions to FTA Guidelines

Agency	Consideration and Potential Constraints to "Lemon Law"	FTA Demonstration Program or Waiver Aspect
Washington	Good, though difficult to enforce. Should be industry-wide finding of poor performance (not just agency with poor procurement). Agency to decide optimum retirement. Ensure funding of remaining years is rolled.	Good, help industry move forward and introduce new technologies.
Toronto	Yes, as corrosion and structural problems made it difficult to maintain vehicles to 12 years.	Procurement of lease of prototypes of buses from different manufacturers to test before selection.
Montgomery	Good idea	(No response given)
Boston	Yes, with constraint that manufacturers ensure integrity and durability (maintain quality with minimal maintenance).	No interest in program
Los Angeles	Yes, if necessary. Option should not be used if normal warranty period is complete, and/or operating cost is substantially different from rest of agency's fleet.	Yes
Frederick	Yes, with conditions of applicability defined. Suggest option only to limited and serious conditions.	Not applicable as a smaller agency with limited staff and capabilities.
Austin	Yes, if dealt with bus supplier.	Yes
Jefferson	Yes, good idea	Not helpful for smaller agencies

Useful Life Waiver for New Technology Demonstration Programs: Table 5-7 also summarizes the agencies' responses regarding interest in and proposals of an FTA demonstration program or waiver aspect to test alternatives concerning service-life requirements. The objective would be for FTA to help encourage agencies to test and adopt new technology vehicles with the guarantee that the agency can retire test vehicles before the service-life minimums have been met if the technology proves problematic.

Summary: Agency Outreach

It is important to note that a survey of nine agencies is not a statistically representative sample; however, the surveyed agencies provide valuable insight on the effects of and recommendations to the current FTA service-life policy. Due to the limited sample size, the initial findings presented in this section can be strengthened with further investigation.

Of the nine agencies responding to the survey, seven have a policy on minimum retirement life not imposed by FTA. This policy is imposed by either the state or the agency itself, and is typically more stringent than the current FTA minimum of 12 years for heavy-duty, larger buses. Moreover, all of the respondent agencies are retiring their vehicles one to five years past the FTA retirement minimums and one to three years past their own, agency-imposed (typically more stringent) retirement minimums. Retirements past the planned retirement age have mainly been driven by the limited availability of capital funding, while early retirements have been caused by high maintenance costs or equipment update. It is important to note that these high maintenance needs are primarily linked to agencies with heavy to severe duty cycles in large metropolitan areas, such as Boston, New York, and Los Angeles.

Agencies recognize the importance of maintenance and overhauls, specifically mid-life, in order to reach and keep vehicles past their scheduled retirement age. However, the timing and extent of these maintenance needs are also limited by the availability of capital funding. Moreover, major mid-life, life-extending overhauls are only performed by a relatively small number of the nation's largest transit operators.

Given these observations, it is clear that the current FTA retirement minimums are not constraining the retirement decisions of most transit operators. Indeed, the retirement ages for the majority of the vehicle retirements documented by this study would not be altered by modest changes (e.g., ± one year) to the current FTA minimums. In fact, several retirement decisions may not be impacted by the removal of the FTA minimums. Key exceptions here are New York and Boston. New York actually changed its policy to not purchase vehicles with federal funds after having to retire vehicles early and reimburse FTA part of the purchase price. Boston would prefer an eight-year minimum retirement to maintain higher quality and avoid the major capital expense of a mid-life overhaul. With these exceptions, the greatest impact of the current retirement minimums occurs when operators find themselves with problem vehicles struggling to meet the FTA minimums. In these instances, agencies are forced to absorb the cost of maintaining the vehicles, place these vehicles on reduced service requirements, and/or seek FTA approval for early retirement.

Despite these observations, many of the agencies recommended several changes to the current FTA policy, such as the potential inclusion of rehabilitation costs as a reimbursable cost and the provision of flexibility/options to agencies in vehicle retirement. Agencies also expressed interest in the potential introduction of a “Lemon Law” allowing early retirement of problem vehicles without financial penalty. Interest in lowering the minimum retirement age was only considered desirable by some agencies as long as the quality of the vehicle is unchanged (i.e., not reduced to a less durable, less expensive vehicle). The benefits of this change would include the reduction in maintenance costs and the ability to implement and keep up with the latest vehicle technologies. On the other hand, extending the minimum retirement age was not considered desirable to agencies expressing concerns over the expected decrease in quality of service to passengers and the increase in maintenance costs.

Vehicle Manufacturer Response

The research team developed an interview guide to assess the current experience of vehicle manufacturers with the FTA service-life requirements. Questions covered areas such as the effects of FTA requirements and regulations, customer (transit operator) useful life expectations, and life expectancy of vehicle components. While a total of nine different North American vehicle manufacturers were contacted for this study, only three manufacturers provided responses and completed the interview guide. **Table 5-8** lists these three vehicle manufacturers and the title of the key contact for their organization.

Table 5-8
List of Vehicle Manufacturer Respondents

Bus Manufacturer	Contact Title	Interview Guide Response Received and Completed
Orion	Director of Engineering	Yes
Optima Bus Corp.	Marketing and Sales Manager	Yes
Millenium Transit	President	Yes

This section synthesizes the responses received in a narrative or tabular format. Not all of the vehicle manufacturers responded to every question. A complete summary of all vehicle manufacturer responses to the interview guide is provided in **Appendix B**.

General Vehicle Useful-Life Expectations

The three vehicle manufacturers that responded to the interview guide surveyed currently manufacture different models of heavy-duty vehicles, with lengths of 30 to 40 feet and capacities ranging from 23 to 47 passengers. Although one of the manufacturers did not provide a detailed listing of its vehicle offerings, all of the manufacturers are in the heavy-duty, 12-year minimum vehicle market. Both of the manufacturers reporting details of their current models stated a minimum life of 12 years, although Orion reports its vehicles have a life expectancy of 18 years, while Optima reports its vehicles have a life expectancy of 12 years. All three manufacturers market their vehicles based on FTA service-life categories.

The manufacturers sell vehicles that are not subject to the Bus Testing Regulation, such as Orion's Sprinter van, which is typically purchased by smaller agencies with local money. The other two manufacturers did not detail specific vehicle models, but Millennium reported that buses sold in Canada (although the same bus) are not subject to these regulations, and Optima has been granted a waiver for additional testing on one of its current models.

With regard to expected service life characteristics requested by their customers, Orion Bus Industries is the only manufacturer to report specific requirement characteristics—Canadian operators look for 18-year service life vehicles, with longer warranty periods and extensive resistance to corrosion for those operators in the Eastern part of Canada where vehicles are affected by the high-salt environment. The other two manufacturers stated simply that agencies are looking for durable vehicles that will last and exceed the minimum retirement ages. However, these manufacturers report that the vehicle retirement age is largely dependent on each individual agency's annual mileage, operating environment (severity), agency maintenance practices, and quality of service standards.

This opinion regarding the impacts of operating environment and duty cycle on the condition/life of vehicles is also reflected in the manufacturers' responses to recommending a mid-life overhaul. Two of the manufacturers reported that they could not recommend specific mid-life overhauls because the vehicle's conditions and the need for a mid-life overhaul depend on each operator's specific annual mileage, environment/duty-cycle, and maintenance practices. The other manufacturer reported neither recommending nor participating in fleet rehabilitations, as these activities offer no benefits to their business. Among the components listed as typically needing replacement are the engine, transmissions, suspensions, and axle. Optima is the only manufacturer that reported providing a recommended component maintenance/replacement schedule, which is included in this report as **Appendix D**. This manufacturer also reported that the approximate cost of replacement of those four components listed above is $18,000 per vehicle.

FTA Minimum Service-Life Requirements

All of the manufacturers stated that they are impacted by the FTA's current minimum retirement ages, and that the 12-year minimum age is a benchmark in this heavy-duty market. Design specifications are driven by the demand of vehicles that will last up to and beyond this 12-year/500,000-mile benchmark, such as the use of stainless steel or aluminum instead of mild steel to meet the corrosion requirements (as reported by Millennium). The manufacturers also structure their marketing strategies around this minimum retirement age (i.e., clearly stating the minimum life standard their vehicles have been tested to meet), which they believe affects the overall demand for their vehicles, the relationship with their customers, and the sales of vehicle parts. One manufacturer specifically stated that a change in the 12-year minimum would directly impact its demand for vehicles and its competing markets (heavy-duty vs. light-duty market).

The argument that reductions in FTA's minimum life requirements would directly result in accelerated vehicle sales and hence a significantly deeper, more sustainable bus market should be tempered by the understanding that very few operators retire their vehicles right at the service-life minimums, due to funding limitations (as shown in Chapter 4 and the preceding section of this chapter). To be clear, a reduction in the FTA minimums would yield some additional sales at the margin, but the increases would not be significant, as most operators do not retire their vehicles until two or more years after the 12-year minimum has been reached. In contrast, *increases* to the service-life minimums by two or more years *would* likely result in a perceptible decrease to annual vehicle sales (see Figure 4-1).

The primary vehicle component listed by all of the manufacturers as being impacted by the FTA requirements is the structure and/or chassis, which is expected to last the 12 years without major failures as it cannot be rebuilt or replaced. Other components listed include the engine, body, axles, suspension, and transmission. However, these were not considered significant to the life of the structure/chassis in determining vehicle useful life.

As previously noted, the only market of customers requesting vehicles with expected life values different than FTA minimums is the Canadian market, where vehicles are specified for 18-year service life. Orion also reported that some of its customers ask for a 15-year design life for the chassis, or other components such as CNG tanks with a service life of 15 to 20 years.

The survey also asked manufacturers about recommendations or changes to the current FTA minimum ages. None of the manufacturers provided or recommended specific changes, and in fact, Millennium reiterated that any changes to these minimums would have negative impacts to its current market. However, two of the manufacturers (Orion and Optima) stated that the FTA minimum retirement ages are arbitrary because they are driven by the FTA Altoona Bus Testing classifications, and manufacturers are able to choose the category under which to test their bus. Thus, there is the potential of buses claiming a false durability of 12 years. Recommendations in this area would include revising regulations to a less arbitrary, more objective, intense testing and providing more detailed reports of the testing results (pass/fail, failure types, etc.).

Vehicle Life Classification

Another section of the survey reviewed the current FTA classifications by vehicle type and intended duty cycle as they relate to the FTA minimum retirement ages, and examined the potential of other alternatives. With regard to the appropriateness of the current FTA classifications, Orion stated that this classification conflicts with EPA definitions and that the categories are not definite enough (weight classes are too loose). Optima reiterated that the minimum retirement ages are based on the FTA Altoona Bus Testing requirements, which make vehicle classification arbitrary as manufacturers choose the category to test under and vehicles receive this classification regardless of length of time to complete or how it holds up. In Optima’s opinion, manufacturers can test buses at the highest possible classification to give them a marketing edge, in spite of the testing results on quality or durability. In short, the manufacturers generally had few concerns with the current categories, but some manufacturers had significant concerns with how those categories are applied in practice, particularly in relation to the bus testing program.

Vehicle manufacturers were also asked their opinion on potential longer-life and shorter-life vehicle options. **Table 5-9** summarizes their responses**.** Two of the three manufacturers (Millennium and Optima) do not believe a longer-life, more durable vehicle can be manufactured because more durable components cannot be produced. If such a vehicle were manufactured, it would be heavier (increased GVW), more expensive, and likely less economical (fuel efficiency, purchase price). The option of a less durable, less expensive vehicle also received differing interest, although the main characteristic and challenge to manufacturing this type of vehicle would be the decrease in component quality (i.e., having to rely on lower-cost components). One manufacturer expressed concerns about the feasibility of manufacturing a safe, shorter life vehicle option that was "cost-neutral" (as compared to existing 12-year models). The concern being that the required reductions in structural cost to make the vehicle cost competitive may also lead to structural issues. Optima stated that another vehicle option for FTA to consider is the new hybrid electric vehicle, with diesel or gasoline engines powering electric motors.

Table 5-9
Opinions on Alternative Set of Vehicle Life Spans

Vehicle Life	Orion	Millennium	Optima
Longer-life, more durable vehicle			
Interest, characteristics of vehicle	Yes – would have to be more resistant to corrosion and heavier.	No – already build most durable buses out there.	No – components would not survive longer life; duty cycle also important in affecting retirement.
Challenges	Encouraging modular design; Rebuild cycles would affect supply of parts.	Supporting technologies for long periods of times	Cannot increase life expectancy of components; Higher price vehicles.
Shorter-life, less durable vehicles			
Interest, characteristics of vehicle	Yes (cater to different needs of transit operators) – lighter weight, lower-cost components.	No – eliminating options, low-cost components.	Not part of market niche.
Challenges	Establishing market.	Getting cost reductions from components, not structure.	Not part of market niche.

Vehicle Components

This section of the survey summarized the manufacturers' experience with individual components and their relationship to the expected service life of vehicles. All of the manufacturers agreed that the life expectancy and maintainability of vehicle components affect the service life and vehicle retirement decision, with the main component being the structure and/or chassis. As previously reported, manufacturers expect these components to endure without major failures in order for vehicles to reach the FTA minimum retirement ages. Millennium also listed the engine, transmission, and axles as vehicle components that also impact service life. On the other hand, vehicle components not affecting service life included seats, radios, fare boxes, glass/windows, and other destination announcement systems. However, two of the manufacturers listed that the life expectancy of engines and brakes are driven by other markets besides the bus industry.

Table 5-10 summarizes the design challenges to vehicle components reported by the manufacturers in the construction of vehicles with increased life expectancy and of vehicles with decreased life expectancy.

As expected, the responses from this section are in line with those reported in previous sections of the survey on the overall life expectancy of vehicles. The FTA minimums impact the design specifications of vehicles, especially the structure and/or chassis, which is a primary driver of retirement decisions because it cannot be economically rebuilt or replaced. The manufacturing of longer-life vehicles is limited by the life expectancy of components, as they are currently not built to last longer or have replacement/maintenance schedules in line with the expected life of the vehicle. Conversely, manufacturing shorter-life vehicles would involve lower-cost, lighter-duty components (such as those in the truck and automotive industry).

Table 5-10
Component Challenges to Vehicle Options

Component Challenges	Orion	Millennium	Optima
Longer-life vehicle	No challenges – 18-year bus already built.	Warranty on engines and batteries remains unchanged	Obsolescence of parts. Affected components: chassis, engines, transmissions, electronic systems, HVAC systems, and others.
Shorter-life vehicle	Take out cost with reduced service life, smaller engines, lighter axles.	Lighter-duty components, mild steel structure.	Downgrade of design, need for change in industry mindset for lower-life vehicles.

Summary: Vehicle Manufacturers

It is important to note that the three vehicle manufacturers surveyed are not a statistically representative sample; however, they do provide valuable insight on the effects of and recommendations to the current FTA policy on useful life of buses and vans. Due to the limited sample size, the findings presented in this section could be strengthened with further investigation.

The general observation is that vehicle manufacturers have built their manufacturing practices and marketing strategies around the current FTA minimum retirement ages, specifically the use of the 12-year minimum retirement age as a benchmark in the heavy-duty vehicle market.

These manufacturers tend to design vehicles with a structure/chassis expected to last and exceed the 12-year minimum without major failures, and with the expectation that other components such as the engine, transmission, and axle follow good maintenance practices to reach these minimum retirement ages. The manufacturers also recognize that the needs of operators differ (18-year minimum in Canada, higher corrosion rate, etc.) and that the operating environment and duty cycle play an important role in the vehicle’s retirement age.

Changes to the current FTA minimums and classifications are closely tied to the life expectancy of vehicle components. Longer-life vehicles would require more durable components, which at this time are not available by component manufacturers, and shorter-life vehicles would entail the use of lower-cost, perhaps lower-quality, components with lower durability expectations.

Private Operators Response

The research team developed an interview guide to assess the current experience of private operators with vehicle retirement ages and the FTA service-life guidelines. Questions covered areas such as factors in retirement decisions, experience with customers (transit operators), and life expectancy of vehicle components. **Table 5-11** provides the list of private operators and the title of the key staff contacted.

Paul Revere Transportation Company provides charters, sedan service, and shuttle service throughout the New England area. Notably, it currently has contracts with:

- Massachusetts Port Authority (MassPORT) to operate the Boston Logan Airport shuttle buses, which provide service through the airport (terminals, satellite parking, and public transportation stations)
- Massachusetts Bay Transportation Authority (MBTA), as the private bus carrier of Route 712 and 713 in the Winthrop area
- Medical Academic and Scientific Community Organization, Inc., providing shuttle service between several medical and scientific-research-related locations throughout the Boston area.

Table 5-11
List of Private Operators Contacted and Respondents

Private Operator	Contact Title	Response to Interview Guide Received and Completed
Paul Revere Transportation Company, LLC	Director of Operations Director of Maintenance	Yes
Abe's Transportation	Operations Manager	Yes
Hertz Rent-a-Car	Director, Operation's Technology	Yes

Abe's Transportation provides charter, limousine, and sedan service and shuttle buses throughout the Washington metropolitan area, including airport transportation, sightseeing tours, and company contracts (service to and from office locations and Metro stations). Hertz provides several rental services, including rental-car services at airport locations where it operates vans and shuttle buses between terminals and at locations on the outskirts of the airport.

This section synthesizes the responses received in a narrative or tabular format. Not all of the private operators responded to every question.

Fleet Characteristics

The three private operators surveyed operate a variety of vehicle types in terms of manufacturer, size and capacity, and duty cycle. As a sample set, Abe's Transportation operates Ford cutaways; Paul Revere operates a number of Neoplan CNGs, Neoplan Diesels, and MCII Diesels; and Hertz operates different sizes of Gillig low-floor clean-burning diesels.

All operators stated performing regular maintenance on their fleets. **Table 5-12** summarizes specific maintenance tasks provided by operators.

Table 5-12
Regular Maintenance Schedule

Private Operator	Maintenance	Notes
Paul Revere Transportation Company, LLC	• Heavy-duty buses are inspected after 12,000 miles. • Light-duty buses are inspected at 3,000 to 4,000 miles. • Exterior and applied panels replaced as necessary (typically 4 to 5 years).	Maintain minimum/maximum spare parts in stock based on experience.
Abe's Transportation	• Oil change every 3,000 miles (manufacturer's recommendation). • Front brake pads changed every 10,000; rear brake pads changed every 17,000 miles (longer for larger, 7-year vehicles). • Front tires changed every 10,000 miles; rear tires changed every 12,000 miles. • Transmission fluids changed every 50,000 miles.	• Ford 6.0 - Warranty of 36,000 miles on transmission, 100,000 miles on engine. • International 3500 – Warranty of 150,000 miles on transmission and engine. • Inspection on all vehicles when washed (1 to 2 times/week).
Hertz Rent-a-Car	Preventive maintenance performed regularly – initially according to manufacturer's recommendation, but now adjusted based on historical data.	Comprehensive maintenance program; Maintenance performed by in-house mechanics

Vehicle Retirement

The private operators were asked to provide information on the expected useful life of their vehicles, as well as the drivers behind the retirement decision. In general, the operators stated an expected vehicle life based on the manufacturer's recommendation, with the options to extend it through transfers to lower-frequency routes or rehabilitation programs.

Paul Revere Transportation provided the following detailed information on the scheduled life and rehabilitation of most of its fleet vehicles:

- 40-foot Neoplan CNG: Scheduled life of 12 years, with an engine rehabilitation at 7.5 years.
- Medium-duty Passenger Vans: Scheduled life of 115,000 miles (approximately four to five years).

- 35-foot RTS Diesel: Scheduled life of five to six years.
- MCII Diesel: Scheduled life of 700,000 miles.

Paul Revere Transportation also stated that structural rehabilitation and/or bodywork on its 40-foot Neoplan CNGs would be performed if the vehicle has a minimum of 12 years and is planned for use after end of contract for other tasks. This operator also stated inspection work is performed on its passenger vans every 5,000 miles due to the large impact from weather.

Abe’s Transportation noted that its smaller cutaways are typically operated on main routes for three years, although it would transfer these vehicles to low-frequency routes after the three-year mark if their conditions remained acceptable. The goal is to keep the larger cutaways for six years, although the vehicles continue operations for an additional year if they remain in excellent conditions. The vehicles do not undergo any overhauls and are traded in after retirement.

Hertz indicated an expected useful life of 12 years based on the bus manufacturers’ design to the federal regulation. Hertz also stated performing one overhaul on the transmission and/or motor in order to extend the vehicles’ life beyond design life. The cost of this overhaul is approximately $20,000 to $30,000.

All of the operators stated vehicle maintenance requirements as one of the main factors behind the decision to retire vehicles. **Table 5-13** summarizes the other factors in retiring vehicles reported by each operator.

Table 5-13
Retirement Factors

Private Operator	Key Factors in Retirement
Paul Revere Transportation Company, LLC	• Age of vehicle – Contracts with customers are often aligned with expected useful life (contract length equal to full or half of the expected life) • Physical condition and quality of service • Duty cycle • Vehicle maintenance requirements
Abe’s Transportation	• Increase in required maintenance cost • Physical condition of vehicles (customer comfort)
Hertz Rent-a-Car	• Perform a return-on-investment analysis of life-cycle costs to trade-off rising maintenance costs as vehicles get older and the purchasing options of new vehicles • Operating conditions (frequency)

Purchase Considerations

The private operators were also asked to provide information on their vehicle procurement process and vehicle purchasing decisions. As expected, none of the three operators surveyed use a low-bid process, and they are mainly focused on customer service and reliability. All of the operators stated they are willing to pay more for the best technology available, for example, luxury models, better fuel economy, computer-aided dispatch, or vehicle location electronics.

Paul Revere Transportation is the only operator surveyed that provides service under a contract with a transit agency. As such, this operator stated that it considers meeting FTA specifications and testing requirements for reliability when purchasing vehicles. Paul Revere also based the length of its contract with these agencies on the expected life of the vehicles. For example, one of its current contracts with MASCO is for six years, for which it operates a 12-year bus. In this case, the firm will not include the purchase of new vehicles in its expected re-bid.

Summary: Private Operators

It is important to note that the three private operators surveyed are not a statistically representative sample. Due to the limited sample size, the initial findings presented in this section can be strengthened with further investigation.

Overall, the private operators are not affected by the FTA service-life policy and evaluate the useful life of a vehicle based on the manufacturer's recommendation, vehicle physical condition, and maintenance requirements. These private operators also apply regular maintenance practices on their vehicles, with rehabilitations and/or overhauls of the larger-size vehicles planned at near the vehicle's mid-life age.

The main factor for retiring vehicles for these operators is the increased cost in required maintenance and the level of service to customer (comfort and reliability). None of the operators use a low-bid procurement process when purchasing vehicles. They consider the higher costs to purchase vehicles with the latest technologies in fuel use, emissions, and/or vehicle location to provide a higher level of customer service.

CHAPTER 6. ENGINEERING ANALYSIS

This chapter provides further evaluation of bus useful life from a bus engineering perspective. To a large extent, this section represents a continuation of the agency outreach analysis from the previous chapter as it is primarily based on the results of both the original agency interviews (see Appendix A) as well as the findings from the second round of agency interviews, this time more closely focused on vehicle engineering-related issues (see Appendix C). A key objective of this section is to highlight the fact that bus useful life is largely determined by the useful life of the vehicle structure. The chapter is also intended to provide an assessment of how transit agencies expect differences in service environment and vehicle characteristics (such as new vehicle designs, propulsion systems, and advanced technologies) to impact vehicle useful life. In most cases, transit agency interview participants have reported that, while they have reason to expect some new technologies and vehicle designs may have minor impacts on expected useful life, most of these new designs and technologies have not been utilized for a sufficient period of time to observe any material impact on actual service life.

Transit Agency Participants – Follow-Up Interviews

Much of the analysis in this section of the report is supported by both the results of the initial agency interviews (as considered in the previous chapter) as well as the results of follow-up interviews completed with a slightly different sample of transit operators (to ensure broader representation for the study) but also with some of the same operators as in the initial sample (because of their familiarity with topics of specific interest, such as CNG buses). The specific sample of seven transit operators included in the follow-up interviews is presented in **Table 6-1**. In contrast to the initial interviews, which included agency staff with differing backgrounds (e.g., bus operations directors, general managers, and vehicle engineering staff), the follow-up interviews were directed specifically towards agency bus engineering staff. The intention of these follow-up interviews was to obtain a more in-depth perspective on engineering issues with useful life implications (e.g., the adoption of new technologies).

Table 6-1
Agencies Responding to Detailed Interview Guide

Operator	Type	Fleet Size (2005 NTD)
Harris County Metro, Houston, TX	Major Urban	1,400 Buses; 229 Vans
LA MTA, Los Angeles, CA	Major Urban	2,815 Buses
MUNI, San Francisco, CA	Major Urban	894 Buses
WMATA, Washington, DC	Major Urban	1,467 Buses; 378 Vans
CATS, Charlotte, NC	Medium Urban	321 Buses; 170 Vans
Lane Transit District	Medium Urban	147 Buses; 92 Vans
Golden Gate Transit, San Francisco, CA	Suburban	321 Buses; 46 Vans

Useful Life of Transit Vehicle Chassis and Components

This section reviews the useful life characteristics of bus and van structures and components. Rather than single, unified objects, buses and vans represent assemblies of numerous components. Hence, the useful life properties of the vehicle as a whole are likewise determined by the components from which the vehicle is constructed. This last statement is true from two differing perspectives. First, the life-cycle cost characteristics of transit vehicles are determined by the life-cycle costs of the components from which the vehicle is constructed. As shown in the next chapter, the overlap of these components' life cycles (some of which last the full life of the vehicle and others which are replaced one or more times over the life of the vehicle) can be used to determine the financially optimal point of retirement. Second, from an engineering perspective, vehicle useful life is ultimately determined by those components with the longest overall life, and primarily the chassis and structure to which all other components are attached.

The following sub-sections consider the useful life characteristics of the primary components of bus and van types within each of the five FTA service-life categories.

Structure/Chassis

Four- and Five-Year Vehicles: Small buses are built on van and cutaway van chassis mass-produced by light-duty automotive manufacturers. The chassis are made from two C-channel frame rails attached by a series of steel cross-members. The chassis supports all major components including the suspension, axle, brakes, wheels, tires, engine, transmission, fuel system, and electrical system. Van bodies and cabs are mounted to the frame rails with bolts and rubber isolators. The van/chassis are designed to last the full service life of the vehicle (i.e., 4 or 5 years) and are not overhauled. The cost of the van/chassis ranges between $20,000 and $30,000.

Seven-Year Vehicles: Vehicles within the 7-year service-life category include buses and trolleybus built on cab and stripped chassis. The chassis are mass-produced by heavy truck manufacturers. The chassis are made from two C-channel frame rails attached by a series of steel cross-members. The chassis supports all major components including the suspension, axle, brakes, wheels, tires, engine, transmission, fuel system, and electrical system. Passenger bodies and cabs are mounted to the frame rails with bolts and rubber isolators. The chassis are designed to last the full 7-year service life and are not overhauled. The cost of the van/chassis ranges between $30,000 and $40,000.

Ten- and Twelve-Year Buses: Heavy-duty small and large buses are built on custom designed or stripped chassis. The chassis designs include integral structure chassis unit body monocoque or semi-monocoque chassis and some body-on-frame construction types depending on the manufacturer. The chassis are made of mild or stainless steel and aluminum alloy from welded tube sections and/or stamped structural panels. The chassis supports all major components including the suspension, axle, brakes, wheels

and tires, engine and transmission, fuel system, HVAC, and electrical system. The chassis of a body-on-frame design (10-year buses) are not overhauled but may be repaired during the life of the vehicle. The custom designed chassis are designed to last the full 12-year service life and are overhauled/repaired as necessary. The cost of a typical midlife overhaul of the heavy-duty custom chassis ranges from $7,000 to $14,000.

Table 6-2
Structure/Chassis Characteristics

Component	4- and 5-Year Vans and Buses	7-Year Bus	10-Year Bus	12-Year Bus
Structure / Chassis				
Type	Van and van cutaway	Cab and stripped chassis	Body on frame construction	Integrated structure chassis unit body monocoque or semi-monocoque chassis
Useful Life	At least 4 to 5 years	At least 7 years or 200,000 miles	At least 10 years or 350,000 miles	At least 12 years or 500,000 miles
Rehabilitated?	No	No	No	Yes*

* Many agencies do not perform a scheduled rehab but will repair as needed

Body

Four-, Five-, and Seven-Year Vehicles: The 4- and 5-year small bus bodies are mounted to cutaway van chassis and designed and built by a second-stage manufacturer. The 7-year medium-duty bodies are mounted to a cab and stripped chassis and are also designed and built by a second-stage manufacturer. A second-stage manufacturer is a manufacturer that receives an incomplete rolling chassis or van and adds necessary components that complete the vehicle and ready it for its intended market. The bodies built for small and medium-duty buses are designed specifically for the transit and shuttle bus markets and feature transit style windows, destination sign, wheelchair lift, and a separate passenger compartment air conditioning system. The bodies are constructed from steel tubes and use either fiberglass or metal for the exterior skin. The 4- and 5-year small bus bodies are attached to the cutaway van chassis and integrated with the driver's cab. The 7-year medium duty bodies are attached to the cab and stripped chassis and integrated with the operator's cab. The cab houses the dashboard, driver interfaces, and driver's seats. The bodies for each of these vehicle categories are designed to last the full service life of the vehicle (i.e., 4, 5, and 7 years respectively).

Ten- and Twelve Year Vehicles: The bodies of 10-year heavy-duty small transit buses are built by two methods—either as an integral part of the chassis structure or as a separate body mounted on a chassis. The bodies of heavy-duty, 12-year transit buses are an integral part of the chassis structure. The bodies of both vehicle categories are constructed from steel tubes or panels and use either fiberglass or metal for its exterior skin, which may or may not be a stressed structural element of the design (i.e., add structural support to the vehicle). As the body of the heavy-duty buses is typically an integral part of the chassis, it is designed to last the full service life of the vehicle, with repairs and overhauls as necessary. The cost of a typical midlife overhaul of the body is $14,000.

Table 6-3
Body Characteristics

Component	4- and 5-Year Vans and Buses	7-Year Bus	10-Year Bus	12-Year Bus
Body				
Type	Mounted to cutaway van chassis	Attached to the cab and stripped chassis	Either integrated with chassis or separate and bolted to the chassis	Integral part of the chassis
Useful Life	At least 4 to 5 years	At least 7 years / 200,000 miles	At least 10 years / 350,000 miles	At least 12 years / 500,000 miles
Rehabilitated?	No	As needed	Yes*	Yes*

* Many agencies do not perform a scheduled rehab but will repair as needed

Interior

Four-, Five-, and Seven-Year Vehicles: The interior of 4- and 5-year small bus bodies and 7-year medium-duty bus bodies use plywood for the floors covered with a rubber flooring material. Interior walls and headliner are covered with lightweight paneling, which is finished off with vinyl or carpeting. Small and medium-duty buses use fabric-covered seats that mount to the floor structure. Transit authorities typically do not refurbish the interior of small or medium-duty buses, but replace worn components on an as-needed basis.

Ten- and Twelve-Year Vehicles: The interiors of 10- and 12-year heavy-duty transit buses use plywood for the floors covered with a rubber flooring material. Interior walls and headliner are covered with lightweight paneling, which is finished with vinyl or carpeting. Heavy-duty transit buses use fabric-covered, solid plastic or stainless steel seats that mount to the sidewalls and/or floor structure. Transit authorities typically do not refurbish the interior of 10-year heavy-duty buses, but replace worn components on an as-needed basis. For 12-year vehicles, operators typically spend roughly $13,000 over the life of the vehicle on interior replacements (either as a comprehensive overhaul or on an as-needed basis).

Table 6-4
Interior Characteristics

Component	4- and 5-Year Vans and Buses	7-Year Bus	10-Year Bus	12-Year Bus
Interior				
Type	Plywood flooring w/ carpeting, light weight vinyl paneling, fabric seats	Plywood flooring w/ rubber covering, light weight vinyl paneling, fabric seats	Plywood flooring w/ rubber covering, light weight vinyl paneling, fabric or solid plastic seats	Plywood flooring w/ rubber covering, light weight vinyl paneling, fabric or solid plastic seats
Useful Life	At least 4 to 5 years	At least 7 years	7 to 10 years	7 to 10 years
Rehabilitated?	As needed	As needed	As needed	Yes*

* Many agencies do not perform a scheduled rehab but will repair as needed

Interior Climate Control

Typical heavy-duty 10- and 12-year vehicles and many 7-year vehicles have heating, ventilation, and air conditioning (HVAC) units that are mounted on the rear of the bus or the roof. The units range in size from 80,000 to 115,000 btu. HVAC system are typically repaired or replaced as needed during the life of the 10-year vehicles. HVAC system are typically overhauled during midlife rehabilitations of 12-year, heavy-duty transit buses, while systems for 7- and 10-year vehicles typically last the service life of the vehicle. The cost for overhauling the HVAC units including interior vents and panels is approximately $10,000. In contrast, most 4- and many 5-year vehicles have heating and cooling systems that are integrated with the body (as in private vehicles) and last the full service life of the vehicle.

Table 6-5
Climate Control Characteristics

Component	4- and 5-Year Vans and Buses	7-Year Bus	10-Year Bus	12-Year Bus
Interior				
Type	Body integrated	Roof Mounted	Roof Mounted	Roof Mounted
Useful Life	Life of Vehicle	Life of Vehicle	6 to 7 years	6 to 7 years
Rehabilitated?	No	No	Sometimes	Yes*

* Many agencies do not perform a scheduled rehab but will repair as needed

Electrical Systems

Many heavy-duty, 10- and 12-year transit vehicle manufacturers use Programmable Logic Control (PLC) technologies, which allow for multiplexing. Multiplexing systems use a single wire databus for communication among major components in a bus. The use of a single wire reduces the number of dedicated wires and relays, and therefore reduces the overall weight and complexity of the vehicle's electrical system and wiring harnesses. Heavy-duty transit vehicle electrical systems typically offer extensive diagnostic capability. The use of the PLC provides for easier diagnosis of sub-systems using software on laptop PCs. The electrical system is repaired as necessary over the life of a 10-year vehicle. In contrast, electrical systems for 12-year vehicles are frequently overhauled at midlife. Typically, a midlife overhaul of the electrical system costs $4,000 on a 12-year vehicle. In contrast, most 4-, 5-, and 7-year vehicles have wiring harness electrical systems (as found in private vehicles) and last the full service life of the vehicle.

Table 6-6
Electrical System Characteristics

Component	4- and 5-Year Vans and Buses	7-Year Bus	10-Year Bus	12-Year Bus
Electrical System				
Type	Wiring harness	Wiring harness	Multiplexing system	Multiplexing system
Useful Life	Life of Vehicle	Life of Vehicle	Life of Vehicle	Life of Vehicle
Rehabilitated?	As needed	As needed	As needed	Yes*

* Many agencies do not perform a scheduled rehab but will repair as needed

Propulsion System

Four- and Five-Year Vehicles: There are two types of internal combustion engines for full-size vans and cutaway van chassis—spark ignition (gasoline) and compression ignition (diesel). The gasoline engines are designed and manufactured by the van and chassis manufacturer. The engines typically have 6, 8, or 10 cylinders ranging in displacement from 4.6 liters to 8.0 liters. The engines are similar to those offered in full-size pickup trucks and sport utility vehicles (SUVs). Gasoline engines in this operating environment have a service life of 125,000 to 175,000 miles. Diesel engines are options on these vehicles at a $4,000 premium. The diesel engines provide superior durability and fuel economy and, with a service life of 250,000 to 300,000 miles, typically outlast the vehicle.

The transmissions are designed and built in-house by the van/chassis manufacturer. The transmissions in operation today have both four and five speeds, which includes overdrive. Transmissions are sized to accommodate the input torque of the engine. Transmission can be expected to last 75,000 to 100,000 miles in transit service. The transmissions are similar to those used in full-size pickup trucks and SUVs.

In this service-life category, performing a mid-life rehabilitation on the bus is uncommon. However, engines and transmissions are overhauled on an as-needed basis. Cost for overhauling an engine and transmission is $4,000 and $2,000, respectively.

Seven-Year Vehicles: Medium-duty buses are powered solely by diesel engines. The engines can be designed and built by the chassis manufacturer or purchased from a dedicated diesel engine manufacturer such as Cummins or Caterpillar. The engines typically have 6 cylinders and 6.0 to 7.0 liters of displacement, and the cylinders are arranged in an inline configuration. Inline configuration is naturally balanced and provides minimal vibration. Diesel engines in this class typically last the bus's life with a service life of 200,000 to 300,000 miles. For medium-duty buses, Allison transmission is the dominate transmission provider. The chassis volumes are not sufficient to warrant chassis manufacturers to design their own transmission. Heavy-duty transmission vendors from Europe have yet to challenge Allison in this bus service-life category. In the category, performing a mid-life rehabilitation on the bus is uncommon. However, engines and transmissions are overhauled on an as-needed basis.

Ten-Year Vehicles: Nearly all of the internal combustion engines used in heavy-duty small transit buses are compression ignition (diesel), although there are some CNG and diesel hybrid powertrains in service. The engines typically have four, six, or occasionally eight cylinders ranging in displacement from 6.0 liters to 8.0 liters in capacity. The engines are similar to those offered in class 7 tractors and straight trucks and heavy duty pick-up trucks. Diesel engines in this operating environment have a service life of approximately 200,000 to 300,000 miles. The diesel engines are supplied to the chassis manufacturer by a diesel engine manufacturer according to the customer's specifications. The major diesel engine suppliers to the heavy-duty small transit industry include Cummins and International. CNG versions can increase the cost of a transit bus by $50,000. Diesel engines can last the entire service life of the vehicles or may be replaced during the service life (depending on the service characteristics of the operator).

The major supplier of heavy-duty, small, transit bus transmissions is Allison. The transmissions in operation today have both four and five speeds. Transmissions are sized to accommodate the input torque of the engine. Transmission can be expected to last to 150,000 miles in transit service, and hence will likely require an overhaul during the life of the vehicle.

Table 6-7
Propulsion System Characteristics

Component	4- and 5-Year Vans and Buses	7-Year Bus	10-Year Bus	12-Year Bus
Propulsion System: Engine				
Type	Gasoline and diesel engines	Diesel engines	Diesel with some CNG and hybrid	Diesel with some CNG and hybrid
Useful Life	Gas: 125,000 to 175,000 miles; Diesel:200,000 to 300,000 miles	200,000 to 300,000 miles	200,000 to 300,000 miles	200,000 to 300,000 miles
Rehabilitated?	Rare	As needed	Yes*	Yes
Propulsion System: Transmission				
Type	Automatic / Manual	Automatic	Automatic	Automatic
Useful Life	75,000 to 100,000 miles	100,000 to 150,000 miles	150,000 miles	150,000 miles
Rehabilitated?	As needed	As needed	Yes	Yes

* Many agencies do not perform a scheduled rehab but will repair as needed

Twelve-Year Vehicles: Nearly all of the internal combustion engines used in heavy-duty transit buses are compression ignition (diesel), although there are CNG and diesel hybrid powertrains in service. The engines have four, six, or occasionally eight cylinders ranging in displacement from 8.0 liters to 14.0 liters. The engines are similar to those offered in class 8 tractors and straight trucks. The diesel engines are supplied to the chassis manufacturer by a diesel engine manufacturer according to the customer's specifications. CNG versions can increase the cost of a transit bus by $60,000, and hybrid powertrains can add $150,000 to the price of the vehicle. Diesel engines have a service life of 250,000 to 300,000 miles and are typically overhauled or replaced on the vehicle.

The transmissions are purchased by the chassis manufacturer according to the customer's specifications. The transmissions in operation today have both four and five speeds. Transmissions are sized to accommodate the input torque of the engine. Transmissions can be expected to last to 150,000 miles in transit service.

In this service-life category, performing a mid-life rehabilitation on the bus is common and typically includes the powertrain. However, engines and transmissions are also overhauled on an as-needed basis. Cost for overhauling an engine and transmission is approximately $35,000 including engine compartment accessories such as mounts and emission control devices.

Axles and Differentials

Four-, Five-, and Seven-Year Vehicles: The axles and differentials used on small buses are exclusively built for the van/chassis manufacture by Tier 1 suppliers. The axles are designed to accommodate the load rating of the vehicle. Most rear axles for this vehicle weight class use a floating design in which the load on the axle is carried by the axle housing and not the axle shafts. The differential provides the final gear reduction and transmits power from the powertrain to the wheels. Properly maintained, axles and differentials will perform for many years without major maintenance. Transit service is hard on axles and differentials and it is not uncommon to have to replace the bearings on the axle shafts or the differential itself. This type of maintenance is not scheduled and is performed on an as-needed basis. Overhauling a rear axle can cost upward to $1,500.

Depending on vehicle's loading rating, the front axle and suspension uses either a solid axle design with coil, leaf, or torsion bar mechanical springs or an independent suspension with either a coil or torsion bar mechanical spring. Independent suspensions provide superior ride comfort, but have more bushings associated with them requiring periodic replacement. Front-axle and suspension systems are inspected regularly with repairs performed on an as-needed basis.

Ten- and Twelve-Year Vehicles: Ten- and twelve-year heavy-duty buses use axles and differentials from the trucking industry although there are transit bus specific axles used especially in low-floor applications where the front axle by necessity must be a low profile design. Rear axles of low-floor designs can also be of a low profile design, but this is only required in a full low-floor type of design compared with the more common partial low-floor design. Heavy-duty small transit buses use two axles and are rated for a GVW of 26,000 to 33,000 pounds, with the front typically rated at 10,000 and the rear at 20,000 pounds. Large heavy-duty transit buses use two axles (3 for an articulated bus) and are rated for a GVW of 36,000 to 40,000 pounds. The maximum axle weight allowed is typically 18,000 front and 22,000 rear depending on the state. As delivered, large heavy-duty transit bus front axles are rated for 13,000 pounds and rear axles are typically rated for 26,000 pounds. Rear axles for this vehicle weight class use a fully floating design in which the suspension loads on the axle are carried by the axle housing and not the axle shafts. Here again, it is not uncommon to have to replace the bearings on the axle shafts or the differential itself and this type of maintenance is not scheduled; it is performed on an as-needed basis and can be expected at least once during the vehicle life. Rear suspensions are most commonly air springs or occasionally solid leaf springs.

The front axle and suspension is generally a solid axle design with coil springs, air springs, or occasionally an independent suspension with air springs. Independent suspensions provide superior ride comfort, but have more bushings associated with them requiring periodic replacement. Front axle and suspension systems are inspected regularly with repairs performed on an as-needed basis. Overhauling heavy-duty axles can cost $9,000 and suspensions roughly $4,600 per rebuild.

Table 6-8
Axles and Differentials Characteristics

Component	4- and 5-Year Vans and Buses	7-Year Bus	10-Year Bus	12-Year Bus
Type	Floating rear, solid or torsion front w/ leaf suspension	Floating rear, solid front w/ leaf suspension	Floating rear, solid front w/ coil springs, air springs	Floating rear, solid front w/ coil springs, air springs
Useful Life	Life of Vehicle	Life of Vehicle	6 to 7 years	6 to 7 years
Rehabilitated?	As needed	As needed	As needed	As needed

* Many agencies do not perform a scheduled rehab but will repair as needed

Brakes

Four-, Five-, and Seven-Year Vehicles: Four- and five-year small buses are equipped with hydraulic brake systems featuring drum brakes on the rear and disc brakes on the front axles. Medium-duty 7-year buses are typically equipped with hydraulic brake systems with either drum or disc foundation brakes. Higher-capacity vehicles are equipped with pneumatic brake systems because of limitation on the boiling point of hydraulic fluid. In transit service, brakes are inspected on scheduled intervals based on either vehicle mileage or time. Brake life is dependent on the duty cycle and can range between 15,000 and 30,000 miles. Rebuilding the brakes can cost upwards of $400 per axle.

Table 6-9
Brakes Characteristics

Component	4- and 5-Year Vans and Buses	7-Year Bus	10-Year Bus	12-Year Bus
Brakes				
Type	Hydraulic; drum rear brakes and disc front brakes	Pneumatic; drum rear brakes and disc front brakes	Pneumatic; drum rear brakes and disc front brakes	Pneumatic; drum rear brakes and disc front brakes
Useful Life	15,000 and 30,000 miles	15,000 and 30,000 miles	15,000 and 30,000 miles	15,000 and 30,000 miles
Rehabilitated?	Yes	Yes	Yes	Yes

Ten- and Twelve-Year Vehicles: Ten- and twelve-year heavy-duty transit buses are equipped with air brake systems featuring drum or disc brakes on the front and rear axles. Heavy-duty vehicles are equipped with pneumatic brake systems because of limitation on the boiling point of hydraulic fluid. In transit service, brakes are inspected on scheduled intervals based on either vehicle mileage or time. Brake life is dependent on the duty cycle and can range between 15,000 and 30,000 miles. Rebuilding the brake system can cost $5,000 including actuators, linings, and drums.

Wheelchair Lifts

Conventional high-floor buses use wheelchair lifts to meet ADA requirements. Low-floor designs also use some form of boarding aid for wheelchair passengers such as an air-driven boarding ramp and kneeling system. The ramps are located on the inside of the bus at the front entrance door and are operated by the driver. These boarding aids use interlocks that prevent the bus from moving with a deployed wheelchair lift or ramp. These systems are repaired as required during the life of the vehicle. Typical overhaul cost for wheelchair lifts at midlife of a 12-year vehicle ranges from $12,000 to $20,000 with ramps costing relatively less depending on the complexity of the mechanism.

Table 6-10
Wheelchair Lifts and Ramps Characteristics

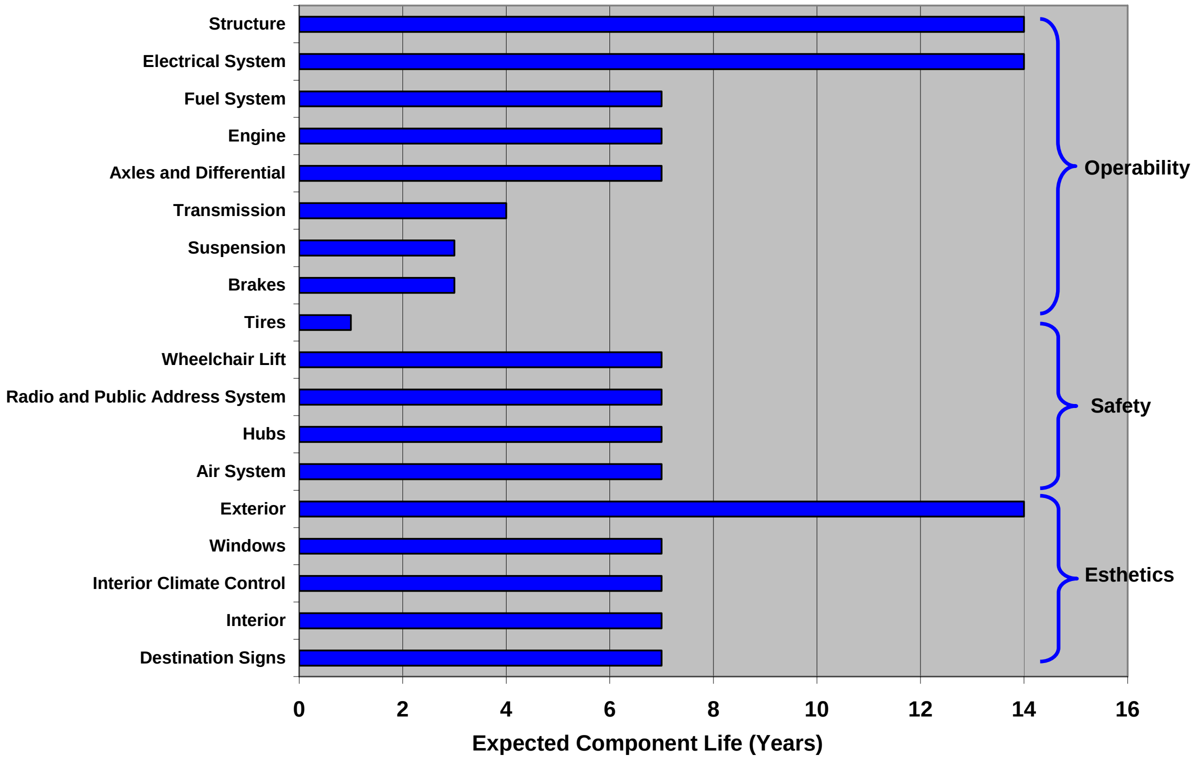
Component	4- and 5-Year Vans and Buses	7-Year Bus	10-Year Bus	12-Year Bus
Type	Lifts and Ramps	Lifts	Lifts	Lifts
Useful Life	Life of Vehicle	6 to 7 years	6 to 7 years	6 to 7 years
Rehabilitated?	As needed	As needed	As needed	As needed

Summary

Figure 6-1 summarizes the results of this sub-section. Specifically, the figure presents the expected service lives of all major component groupings for a 12-year bus. Here, component groupings have been placed into three categories acting as rough prioritizations of vehicle replacement and rehabilitation importance. These include (1) replacements required to keep vehicles fully operable, (2) replacements to ensure vehicle operation remains safe, and (3) replacement/rehabilitation activities to maintain/improve vehicle esthetics (or general quality of service). Note here that relatively few vehicle components typically last the full “service life” of the vehicle. For 12-year vehicles, this includes the structure (the component to which most other components are attached), exterior (panels or “skin”), and the electrical system. This summary presentation helps to emphasize the fact that the vehicle structure, the skeleton to which all other components are attached, is the single most important vehicle component that defines the overall useful life of the entire vehicle. Given this importance, the next sub-section will further review the vehicle frame.

Figure 6-1

Component Expected Life: 12-Year Bus



Vehicle Structure – A Second Look

This section provides further consideration of vehicle structure. As noted above, vehicle structure defines the useful life of the vehicle as a whole more than any other single vehicle component. This is because the structure is the backbone to which all other vehicle components are ultimately attached. Should the structure wear out or fail due to the influences of corrosion or a significant accident, then the life of the vehicle is essentially at an end. In contrast, other vehicle components can be replaced as needed when they fail or become obsolete. This even includes components that can be challenging to replace, such as electrical systems, which may require significant dismantling of the vehicle prior to removal and replacement. Even the vehicle exterior (e.g., the panels making up the "skin" of the vehicle), which also tends to last the expected service life of the vehicle, can be replaced as needed over the life of the vehicle. Replacing the structure, however, would require the removal of all other components and then the complete reassembly of the vehicle—an improbable task.

As the Chapter 2 analysis makes clear, the structure of the 12-year bus (and some 10-year buses) is really only the bus and van structure developed *solely* for the transit market, with the structures for all remaining bus and van types developed with other user applications in mind, such as school buses, motor homes, courtesy vehicles, and family vans. Given that structure defines vehicle useful life more than any other component and that 12-year vehicle structures are the only structures designed specifically for transit use (and transit is the largest purchaser), the 12-

year structure is the single component where FTA and the transit industry are in the best position to alter both component life and vehicle useful life simultaneously.

The following sub-sections consider the useful life of vehicle structure from two different perspectives. The first is the impact of service environment, which is a primary determinant of structure service life and a factor that many transit operators would like to include, along with service years and miles, in assessing FTA’s minimum service-life requirements. The second is consideration of how different structure designs impact the useful life of transit buses. For the most part, the discussion in the section is limited to 12-year buses.

Service Environment

All of the agencies interviewed for this study, including those participating in both the initial and follow-up reviews, acknowledged that service environment is one of the most significant factors that impacts the useful life of the bus structure. This was recognized by agencies whether they considered their own service environment as less, the same as, or more severe than the national average.

Agencies who noted that their service environment was the same as or less severe than the average did comment that buses that see high passenger load rates and are subjected to more severe service wear out faster. This is intuitive, and most agencies can proactively address this by rotating their buses so that the vehicles get equal exposure to the high service routes in order to balance overall fleet life. However, this is not always possible. One agency noted that they exclusively used 60-foot articulated buses on specific high demand routes. These buses experienced much higher wear and required more maintenance. This agency attributed the higher maintenance requirement to the more demanding service environment served by the 60-foot bus rather than to the complexity of the articulated vehicle.

The variability in service environment and its impact on bus useful life implies that a standard replacement age may not be appropriate for all transit agencies. A bus structure built to survive the standard 12 years in an average North American city will not last 12 years in a harsher New York City or Boston environment. Conversely, a bus structure built to survive 12 years in either of these northeastern cities will be over-designed for the average U.S. transit agency. The bus structure will survive in excess of 12 years, but it is a heavier and stronger structure. The additional weight of the structure results in lower passenger capacity, higher fuel consumption, and greater wear on suspension and braking components. Many of the agencies interviewed (including TTC, NYCT and MBTA) have strengthened their specifications to include structural validation requirements in order to ensure they are purchasing buses that will survive for their desired (e.g., 12 year or longer) useful life within tough operating environments.

TTC and NYCT working with Bodycote (formerly Ortech) developed an evaluation process to pre-qualify bus structures using a shaker table test. The shaker table can be used to simulate the bus in the agency’s actual operating environment. The shaker table consists of four hydraulic posts that attach to the bus’s wheel ends. The hydraulic posts input loads into the bus’s structure based on accelerometer data collected from actual routes. The dynamic test can simulate 500,000 miles of actual operation in a matter of weeks. The actual stresses and failures that a bus structure would experience in service can be found over the course of the test.

Using a similar methodology, the stresses imparted into the bus structure can be measured in service and used to calculate “damage factors” for the structure. Instead of testing a completed bus on a shaker table, this method can be used to predict useful life. This approach has been applied by the MBTA on all of their recent bus procurements. Each bus design was outfitted with a few dozen to a couple of hundred strain gauges and road tested in both loaded and unloaded conditions. The strain/stress data gathered from these tests was then extrapolated over the required 500,000-mile useful life of the bus. By comparing this information with known fatigue curves for standard welded joint classes, the expected life of the bus structure can be determined. In addition, any locations that may have a lower than required life can be identified and redesigned prior to full bus structure production.

Based on the interviews with transit agencies, it is clear that service environment has a significant impact on bus structure useful life. However, because of the wide range in service environments throughout the country, agencies with the most severe service environments have found it necessary to emphasize bus structure validation as part of their evaluation process. If all agencies are required to get 12 years of useful life from their buses, this will result in the average agency purchasing a vehicle that is over-designed for their needs at a higher cost, with operating penalties of increased weight and/or reduced passenger capacity.

Severity and Minimum Service-life requirements

Finally, the question then arises as to whether the service environment should be included—along with minimum service years (e.g., 12 years) and service miles (e.g., 500,000 miles)—in the definition of FTA’s expected minimum service-life requirements. In other words, should agencies operating in severe service environments be subject to less restrictive minimum service-life requirements as compared to those in less severe environments (e.g., 10 years versus 12 years for a large heavy-duty bus)? While many of the interview respondents support the lesser restriction, it is not clear how this service environment adjustment would be implemented in practice. For example, how would service environment severity be measured and where does the boundary between severe and not severe lie? Presumably, this would require some type of index incorporating measures of average passenger loadings, street “roughness,” road salt utilization, and perhaps local topography (i.e., for presence of steep grades). Alternatively, agencies could lobby for a severity rating that FTA would then need to agree to.

At the same time, FTA would also need to conduct some analyses to determine how the minimum age and mileage requirements should best be altered to reflect these differences. For example, for large, heavy-duty buses, should the service-life requirements be 10 years for high-severity environments, 12 years for average severity environments, and 14 years for low-severity environments, or some other set of ages?

Another option would be to maintain the current 12-year and 500,000-mile requirements and then somehow adjust funding levels to reflect the needs for a stronger structure for more severe operating environments. To a limited extent, this is already the case as (1) formula funding is already tied to ridership (thus accounting for rider impacts if not street roughness impacts) and

(2) FTA funds 80 percent of the vehicle cost, including 80 percent of the higher cost for vehicles with stronger structures.

In summary, while it is very clear that service environment severity is a primary determinant of vehicle useful life, it is not as clear how this factor could be represented in FTA's minimum service-life requirements. While it is possible in theory to develop measures to capture and reflect differences in service environment severity (e.g., an index of service severity), selection, development, and reporting of these measures would require some research and would still require identification of a clear (but arbitrary) cut-off point between the severe and less severe environment types.

Construction Type

The method in which transit buses are designed and constructed has an impact on their useful life. The most popular method of construction used today for 12-year service life buses is an integral body and chassis constructed from square tubing. This construction method uses hundreds of varying sizes of square tubes that are welded together to form the sidewalls, roof, and floor structures. The sections are brought together and welded creating an integral bus body and chassis. There are thousands of welds in a completed bus structure and the welds are subject to fatigue. Buses that use this construction method are commonly referred to in the industry as "stick" buses. European bus designs heavily influenced this construction method. New Flyer, Orion, NABI, and Neoplan all employ this type of construction.

The advantage of this construction method is that very little tooling and few machines, if any, are used in fabrication—thus minimizing expenses related to introducing a new bus design. Disadvantages include the fact that the buses are very labor intensive to build and early versions suffered from structural design deficiencies, corrosion problems, and general quality control issues—leading in turn to useful life issues. Many transit authorities stayed with the proven General Motors RTS design last manufactured by NovaBus and Flxible's Model 870, both of which were high-floor designs. With the advent of low-floor buses, however, even the most loyal RTS operators were forced to procure stick buses—the more effective design for vehicles of this type. Most manufacturers have addressed the issues previously associated with stick buses by treating the tubes with corrosion-resistant coatings, employing stainless steel, improving quality control, and strengthening the design such that newer designs are expected to have better useful life expectancies as compared to earlier models.

Low-Floor Designs

Low-floor buses entered the market in the early to mid-1990s. These buses feature a dropped front axle that enabled the floor to be lower and thereby eliminated the need for entry steps. They also eliminated the need for wheelchair lifts, which were problematic to maintain. In the U.S. market, the low-floor bus standardized around a configuration featuring a low floor that ran from the front of the bus to just aft of the rear door. After which, two steps are required to reach the rear platform. The raised rear platform provides sufficient space under the floor for a conventional rear axle and powertrain.

Most of the 40-foot transit buses sold today are of the low-floor design. Interview participants stated that it is too early to tell whether the low-floor design will impact vehicle longevity, but did note that this design is more susceptible to roadside damage and salt spray (because the floor structure is closer to the ground). Furthermore, the front suspension travel is reduced due to space limitation, which may result in greater loads imparted into the bus structure with possible long-term service life ramifications. Some interview participants felt that the service life of low-floor buses would be less than that of high-floor buses, although they are capable of meeting minimum service-life requirements. Others responded that the service life should be similar.

Articulated Bus Designs

Articulated buses were introduced in the U.S. market in the 1980s by European manufacturers. Two configurations were sold. In one configuration, commonly referred to in the industry as a "pusher," the engine resides in the rear of the second module or "trailer" similar to a conventional 40-foot bus. The other design, referred to as a "puller," houses the engine below the floor of the forward module or "tractor." The added complexity of articulated buses increased their maintenance costs, which can reduce their useful service life. Only a few large transit authorities operate articulated buses in significant numbers. Transit authority responses did indicate issues with articulated buses, but these issues were primarily vendor-specific and not necessarily typical of this vehicle type.

The advent of bus rapid transit (BRT) has renewed interest in articulated buses. These latest designs feature low floors, stylistic front ends, pusher powertrain layouts, and in some cases doors on both sides of the vehicle. It is premature to comment on the durability of the latest generation of articulated buses; however, features such as doors on either side would be expected to challenge the structural integrity of the bus and could negatively affect its useful life.

Bus Durability and New Technologies

Promoting research into advanced designs and technologies has always been an FTA interest and a transit industry strength. In the 1990s, FTA performed research on battery electric, hybrid electric, alternative fueled, fuel cell, and composite material buses. This research has led to some useful-life impacts on the grantees. For example, the composite structures can certainly provide a minimum 12-year life, and likely more. These may be of interest to agencies looking for longer-life vehicles. However, the cost of the composite buses has limited their competitiveness within the low-bid procurement process.

The following subsections consider the useful life implications of two types of new vehicle technologies—alternative fuel and new electronics technologies.

Alternative Fuels and Hybrid Propulsion Systems

The use of new fuels and propulsion systems in transit has historically affected the reliability and (in some cases) useful life of transit buses. Early compressed and liquefied natural gas engines, for example, were sensitive to fuel quality and the energy content of the fuel because their mechanical fuel injection systems were not sophisticated enough to adjust for these differences and often led to engine damage. Newer electronically controlled engines have solved issues associated with changes in fuel content.

Natural gas engines operate with a lower compression ratio. The lower ratio results in smaller forces on the pistons, pistons rod, crankshaft, and crankshaft bearings theoretically extending the life of the lower half of the engine. The high combustion temperatures associated with spark-ignited engines negatively affect the upper half of the engine. Taken together, CNG engine should have similar life to that of diesels, which is approximately 300,000 miles.

Survey responses from transit authorities found modern CNG engines to be durable and reliable. Some transit authorities commented on the increased maintenance requirements due to the added components such as the spark plugs and ignition systems. Transit authorities' current concern with CNG buses is their higher curb weights. CNG buses weigh approximately 3,000 lbs. more than their diesel counterpart. The added weight is associated with the high-pressure cylinder storage tanks that make up the fuel storage system. Some transit authorities expressed concern that the added weight negatively affects the useful life of transit bus structures. Hence, while the engine life of CNG vehicles may be comparable to that of traditional diesel engines, the higher CNG engine weight may have negative useful life impacts on vehicle structures. The agency respondents stated that this has yet to be proven.

Diesel hybrid electric propulsion systems are the latest technology employed on transit buses. Hybrid propulsion systems feature a diesel engine, generator, electric traction motor, power electronics, and batteries. The batteries are capable of storing energy from regenerative braking and using it later to propel the bus. NYCT was the first transit authority to purchase diesel hybrid electric buses in 1998. Since that time, the technology has developed, additional suppliers have entered the market, and the technology has gained widespread acceptance. Diesel hybrid electric buses have proven successful in terms of reliability and maintainability, and the regenerative braking feature has significantly reduced brake maintenance.

Diesel hybrid electric propulsion systems have two issues that may impact bus useful life. The first issue is the life expectancy of the batteries. There are currently two battery types being used on transit buses—lead-acid and nickel metal hydrides. Neither is capable of meeting the minimum life expectancy of a transit bus; both will need to be replaced one or more times throughout the vehicle life cycle. Transit authorities will have to decide whether it makes economic sense to install new batteries at a significant expense into an older bus or retire and buy new. The second issue deals with weight. The weight of the batteries and associated components is approximately 1,500 pounds. While not as significant as the weight with CNG buses, the additional weight increases roof loads onto the structure and may impact useful life. Here again, the actual impact on vehicle useful life will not be known until these buses begin to reach their mid and later service years.

New Electronics Technologies

Over the past decade, transit operators have added an ever-increasing number of new electronics technologies to their bus vehicles, including automatic vehicle location, automatic passenger counters, on-board cameras, vehicle diagnostics, adaptive signal timing and communication control, voice annunciation and others. In many instances, agencies will not allow their buses to pullout for daily revenue service unless these systems are fully functioning (in some cases, for liability concerns). However, as each new technology is added to the bus, and as more of these technologies are deemed critical to service operations, the probability of one ore more technologies failing steadily increases, leading to a potential need for increased spare ratios. Of greater concern to agencies is the fact that the likelihood of these technologies failing is expected to increase further as vehicles age, leading to potentially serious fleet reliability issues for aging fleets (or an increased need for vehicle electronics overhauls after mid life). Once more, the ultimate impact on vehicle useful life will not be known until these technologies have been in service for many more years.

Life-Extending Practices

Life-extending practices employed by transit authorities include the use of corrosion-resistant materials, preventative maintenance programs, and mid-life overhaul programs. Many transit authorities specify corrosion-resistant materials when procuring buses. These include the use of protected carbon steel and stainless steel. The interior of the tubes are treated with an interior rust inhibitor, while the undercarriage is also treated with an undercoating. Corrosion-resistant metals, rust inhibitors, and undercoating are imperative to ensuring a long useful life.

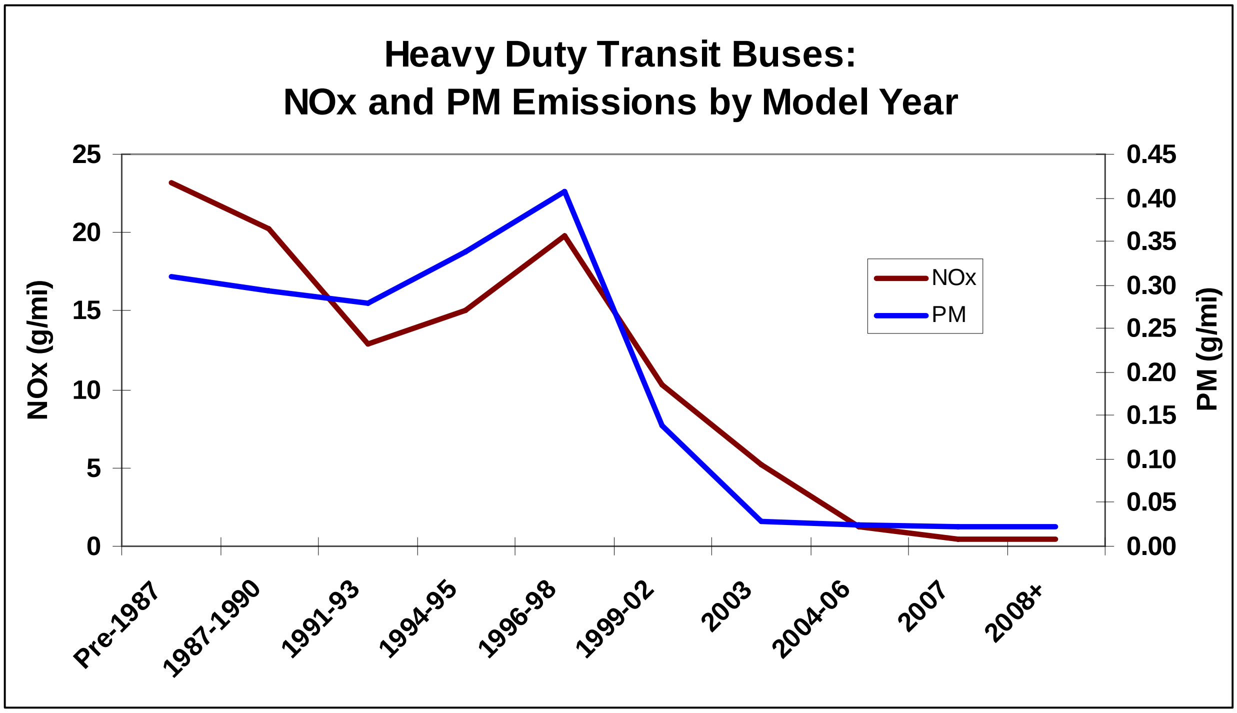
Similarly, preventative maintenance programs are key to ensuring minimum life requirements are satisfied. Operating buses with worn or bad suspension bushing, for example, increases the loads imparted into the bus’s structure and ultimately shortens the useful life of the bus. Typical preventative maintenance programs might include a 3,000-mile minor mechanical and 12,000-mile major mechanical and inspection.

In addition to preventative maintenance programs, some of the nation’s largest transit authorities perform mid-life overhauls after roughly seven years of service. The overhaul programs are extensive and result in the rebuilding or replacing of a majority of components on the bus. The work can be performed in-house or by an outside contractor. Transit authorities that engage in mid-life overhaul program typically extend the service life to 15 years.

Vehicle Emissions

An additional consideration with respect to bus and van useful life and FTA’s minimum service-life requirements is vehicle emissions of nitrogen oxides (NOx) and particulate matter (PM). First, although it is difficult to obtain empirical data on the matter, it is generally believed that vehicle engines emissions gradually worsen over the life of the vehicle, as the condition of the engine continually declines (even with rebuilds). Second, and more importantly, emissions levels for new heavy-duty transit buses have been decreasing steadily over time, as newer, cleaner burning engines are developed (see **Figure 6-2**). Either way, it is clear that any reduction in actual vehicle service life (i.e., earlier fleet retirements) can help accelerate the replacement of older vehicles (and engines) with newer vehicles with cleaner burning engines yielding a clean air benefit to society. However, as has been noted many times throughout this report, FTA’s current minimum life requirement is not binding for most transit operators—and hence, any relaxation of that requirement would not yield an appreciable reduction in transit fleet particulate emissions. (See Financial Impact of Earlier or Later Bus Retirement in the next chapter, which estimates the small number of vehicles likely to be retired earlier with a reduction in FTA's minimum service-life requirements.) Moreover, it has not been shown that the benefits of this emissions reduction would offset the increased capital cost for accelerated vehicle replacement. Finally, even if more agencies were responsive to a reduction in FTA's minimum service-life requirements, the emissions benefit from accelerated retirement would be short-lived. As shown in Figure 6-2, new engines are now nearing zero-emissions levels for NOx and PM. Once all of the older, "dirtier" vehicles are retired, the benefit of accelerated retirement disappears.

Figure 6-2



Source: California Air Resources Board, Urban Diesel Transit Bus Emissions Inventory

Vehicle Reliability

The impact of age on a bus's useful life varied by transit agency and was primarily influenced by the agency's maintenance practices and service environment. While all agencies reported that buses became less reliable with age, it was noted that the extent of unreliability and deterioration could be controlled and/or mitigated by improved maintenance. In general, agencies that followed a rigorous preventative maintenance regime reported that they saw minimal deterioration of the bus over the 12-year expected life. Agencies that performed primarily corrective maintenance reported that older buses became less and less reliable and more and more expensive to maintain.

National Bus Condition Assessment

From 1999 to 2002, FTA’s Office of Budget and Policy completed a series of physical condition inspections for a large sample of U.S. transit buses. This study evaluated the physical condition of close to 900 transit buses and vans at more than 40 different transit properties. The purpose of these inspections was to develop bus vehicle decay curves to simulate the nation’s current and future bus replacement needs within FTA’s TERM.

The bus physical condition data collected for this effort provide valuable information on: (1) the expected physical condition of U.S. transit buses throughout the vehicle life cycle and (2) a clear understanding of how the physical condition of transit buses of the same age varies across bus models and transit properties. The results of this condition assessment provide a valuable means to understand both the consequences of the existing minimum service-life requirements (e.g., the expected physical condition of a 40-foot transit bus at age 12) as well as the consequences of changing that policy (e.g., how increasing or decreasing the minimum retirement age would impact the physical condition of the nation’s bus transit fleets). This section provides an overview of FTA’s bus condition assessment program and its findings as they relate to FTA’s minimum life requirements.

National Bus Condition Assessment – Overview

The national bus condition assessment evaluated the current physical condition of 895 transit buses and vans located at 77 facilities from 43 different U.S. transit properties. In practice, each assessment consisted of a detailed on-site evaluation of the current physical condition of several vehicles of each sub-fleet located at each sample agency maintenance facility. For bus vehicles, the assessment included a detailed inspection of the vehicle's interior, exterior, chassis and understructure, and engine compartment. This visual inspection data was then combined with agency maintenance hours, road call, fluid analysis (e.g., oil sample), and other data to yield a comprehensive evaluation of each vehicle's overall physical condition.

The primary goal of the national bus condition assessment was to provide FTA with this "snap shot" of the current physical condition of the nation's bus fleet and related maintenance assets. This national condition evaluation is significant as it provides a critical measure of the quality and safety of transit service currently provided to the nation's bus riders. At the same time, by revealing the distribution of physical conditions of the nation's bus fleets (e.g., across vehicle ages), the assessment also provides a realistic basis for evaluating the nation's immediate vehicle and facility replacement needs. This analysis of the FTA service-life policy used this bus condition assessment to help establish an engineering basis to the minimum useful-life service measures of age and miles.

A secondary project goal for the national bus assessment was to develop improved asset decay curves of bus vehicles and bus facilities for FTA's TERM. TERM itself is designed to predict current physical conditions and long-term capital needs for the U.S. transit industry. Given these capabilities, TERM is also the primary analytical tool used by FTA to prepare its condition and needs estimates for the biennial U.S. DOT report to Congress. In developing those estimates, TERM uses statistical decay curves to model the life cycle of all transit asset types, including bus vehicles and related facilities. These condition decay relationships were used in this contribution to the useful-life analysis.

Considerable care was taken to ensure that the vehicles and transit agencies included in the inspection process yielded a representative sample of the nation's bus fleet and agencies as a whole. This objective was achieved by first examining both the overall characteristics of the nation's bus fleets and related facilities and the prime determinants of the physical decay processes for these asset types (e.g., variations in passenger loadings, average miles per year per vehicle, and climate). The sample of assets for inspection was then selected to ensure a representative sample based on these national characteristics and one with sufficient data points to permit comprehensive statistical analysis of the asset decay process for buses and facilities. This representative sample is equally important to this engineering analysis of the useful life of buses and vans.

Overview of Key Results

The national bus condition assessment yielded several significant results regarding the physical condition and asset decay characteristics of the nation's bus vehicles. These include the following:

1. The rate of decay for bus vehicles appears to fall into three distinct regimes over the asset life cycle—being highest over the first five years of revenue service, slowing markedly between the ages of 5 through 14, and then accelerating again as the vehicle approaches retirement. These observed regimes are consistent with the known service and rehabilitation practices of U.S. transit operators throughout a typical vehicle life cycle. In general, most transit agencies obtain their highest revenue mileage and conduct the least amount of rehabilitation activities over the initial years of vehicle revenue service (i.e., producing a high decay rate). Between the ages of 5 and 14 (approximately), vehicles see less revenue service and begin to undergo multiple, small rehabilitation activities—reducing the rate of decay. Finally, the value of maintaining a low-service vehicle approaching retirement declines continuously after the age of 14, leading to significant reductions in rehabilitation activity and, consequently, a rapid increase in the rate of decay.
2. On average, agencies pursuing aggressive preventive maintenance programs tended to experience lower overall maintenance costs, superior bus conditions (a lower rate of deterioration), and extended vehicle life. In contrast, agencies focused primarily on corrective maintenance tended to exhibit poorer overall conditions, higher maintenance costs, and higher vehicle failure rates.
3. Overall, the primary contributors to vehicle decay were high utilization rates, salt-related corrosion (highest in regions using road salt and/or adjacent to salt water), and weak preventive maintenance. Many vehicles also suffered from the effects of vandalism.
4. While the national condition inspections covered all bus and vehicle types, the inspection effort was concentrated on 12-year buses. Consequently, the data quality is highest for this vehicle type and much of the analysis that follows relate specifically to findings for the 12-year vehicle type.

Vehicle Condition Rating Criteria

The condition rating criteria used in the bus condition engineering analysis is based on a five-value measurement of every detailed component and element within each bus (**Table 6-11**). The 1 to 5 condition rating scale used here is derived directly from that used by FTA to report asset conditions for all transit asset types at the national level. Every component was assessed in this process based on a detailed valuation description of the five measures for each component.[5] These component condition ratings were subsequently entered into a national bus condition assessment database and the overall physical condition of that vehicle calculated as the weighted average of the condition ratings across all vehicle components. The component weights assigned for this calculation are equal to each component's estimated percentage contribution to the total life-cycle capital cost of the vehicle (including the component's purchase price, capital maintenance, and rehabilitation and replacement costs as applicable).

The condition assessment engineers observed a broad variation in the rate of vehicle decay across the transit agencies participating in the study. For example, on average, 40-foot buses were observed to take 8.4 years to decay from condition 5.0 ("excellent") to condition 3.0 ("adequate"). However, this decline took only 5.1 years for the lowest ranked operators included in the study. For the highest ranked operators, this decay process required 13.5 years—one year past the FTA's minimum retirement age.

Table 6-11
Vehicle Condition Rating System

Rating	Condition	Description
5.0	Excellent	No visible defects, near new condition
4.0	Good	Some (slightly) defective or deteriorated component(s)
3.0	Adequate	Moderately defective or deteriorated component(s)
2.0	Fair	Defective or deteriorated component(s) in need of replacement
1.0	Poor	Critically damaged component(s) or in need of immediate repair

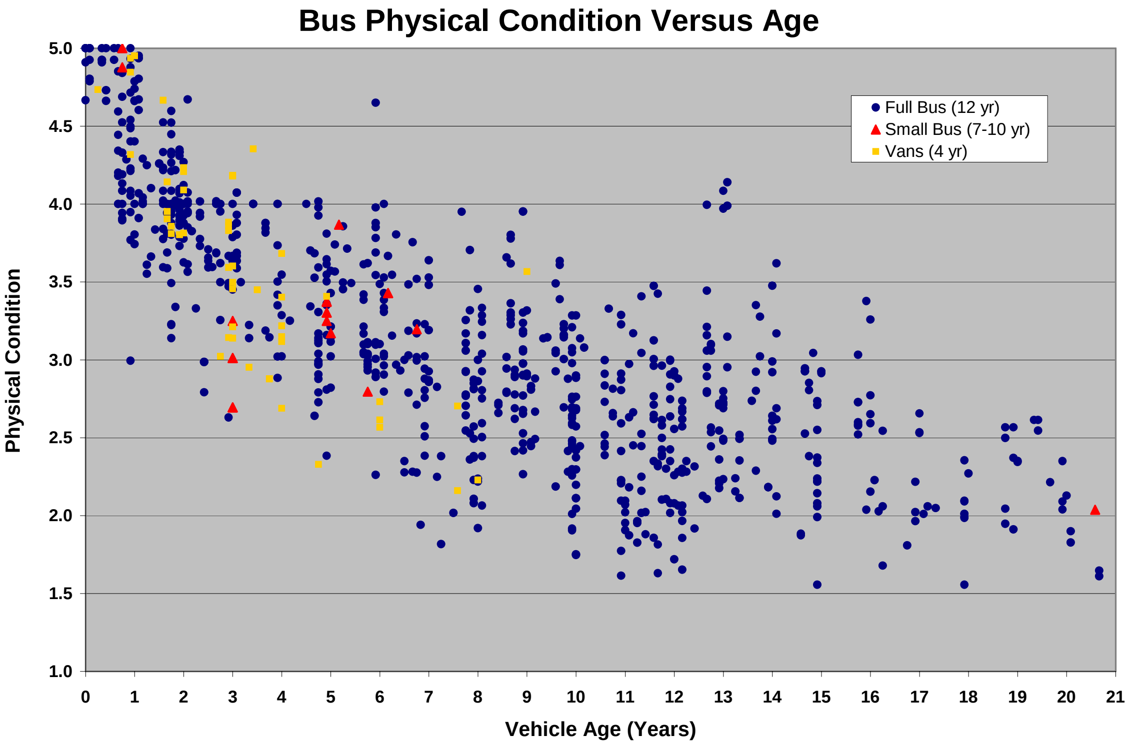
Bus Vehicle Conditions

Figure 6-3 provides a scatter plot of the observed vehicle conditions for the 895 transit buses and vans. Specifically, each point represents the weighted average condition value for a single vehicle based on the assessed condition of that vehicle's constituent components. As expected, vehicle conditions decline significantly over the life of the vehicle—starting in excellent condition (5) and deteriorating to marginal or poor condition (2 or 1 approximately) over a 10- to 20-year period.

---

[5] *For more information about the TERM model or details of the bus condition assessment process, please reference "Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance" and the "Transit Economic Requirements Model Users Guide."*

Figure 6-3



This figure also reveals broad variation in the *rate* at which vehicles deteriorate. For example, while most 12-year vehicles tend to remain in the good through excellent range (ratings 3.5 to 5) during the first two years of revenue service, several vehicles appear to fall quickly below this level. This rapid rate of decline was typically the result of very high service levels, high passenger loadings, accidents, and in a few instances vandalism. At the same time, many 12-year vehicles were in adequate (condition 3) or better condition well past the FTA's 12-year minimum retirement age. These well-preserved vehicles were typically the product of strong preventive maintenance programs, milder operating environments, and lighter duty cycles. Relatively few 12-year vehicles had an overall condition rating less than 2.0 (although many individual vehicle components were assigned a condition rating of 1). This result reflects transit agency reticence to place a vehicle in active service if it has deteriorated such that it represents a safety hazard, has poor reliability, or provides poor service quality.

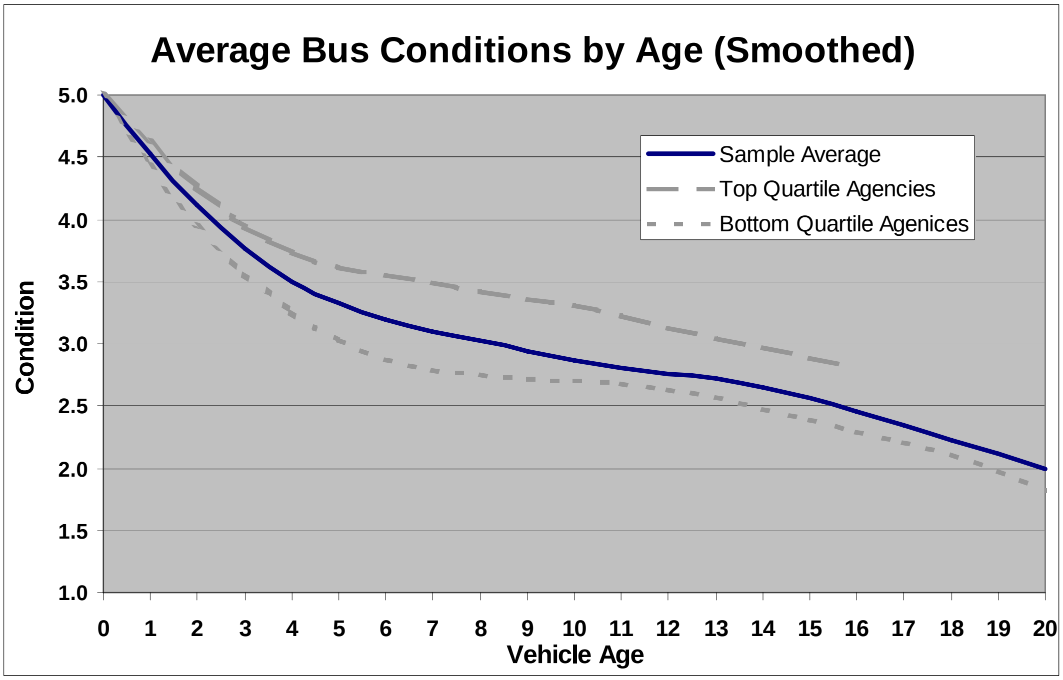
Implications for FTA’s Minimum Service-life Policy: Part 1

For this review of FTA’s minimum service-life policy, an overall vehicle condition rating of 2.0 means a reasonable floor beneath vehicles should not generally be permitted in service. In other words, an overall condition of 2.0 helps to establish a *maximum* replacement life point (not a *minimum*). By inference then, vehicles with ages equal to FTA’s minimum retirement age (or mileage) should have overall condition ratings that are *greater* than 2.0. Specifically, this minimum retirement age should optimally occur after a vehicle type has declined below a condition rating of 3.0 (i.e., adequate) but before it reaches an overall condition of 2.0 (substandard).

Average Vehicle Condition by Age: 12-Year Vehicles

Figure 6-4 illustrates the change in average vehicle conditions by vehicle age for the full sample of 12-year vehicles once the scatter plot data presented above are "smoothed" to better capture the rate of vehicle decay for different bus populations.[6] Inspection of this smoothed average graph reveals several significant features. First, as expected, average vehicle physical conditions tend to decline as vehicle age increases. Second, the rate of decline is not constant, but varies over time. In particular, the rate of decline appears to fall into three distinct regimes over the asset life cycle—being highest from procurement through age 5 (approximately), slowing markedly from age 5 to 14, and then accelerating again after age 14. Finally, the rate of decline decreases slowly from year to year within each regime, appearing to follow an exponential decay process within each regime period.

Figure 6-4



As shown in **Table 6-12,** the observed deterioration regimes are entirely consistent with the known service, maintenance, and rehabilitation practices of U.S. transit operators throughout a typical vehicle life cycle. In general, most transit agencies obtain the highest revenue mileage from bus vehicles during their initial years of service (ages zero through five approximately). During this period, the vehicles require the least maintenance and provide the highest quality service to transit patrons in terms of comfort, cleanliness, and reliability. The lower rate of

---

[6] *Specifically, Figure 6-4 presents a smoothed average of the data points first presented in Figure 1-2. The smoothed average was calculated by first computing the observed average condition rating value at each vehicle age. These observed average age values were then "smoothed" such that the smoothed average value for age t was set equal to the observed average values for ages t, t-1 and t+1 (i.e.,* $\text{Smoothed Average}_{\text{Age } t} = 1/3*\{\text{Average}_{\text{Age } t-1} + \text{Average}_{\text{Age } t} + \text{Average}_{\text{Age } t+1}\}$*).*

capital maintenance and high rate of utilization combine to produce the highest rate of asset decay during this time period.

Table 6-12
12-Year Vehicle Decay Rate Regimes

Age Regime	Vehicle Ages	Rate of Decay	Agency Practices
"Like New"	0 to 5	Highest	• High annual mileage • Minimal/no rehabilitation (near new condition)
"Mature"	5 to 14	Moderate	• Reduced annual mileage • Significant rehabilitation activity (engine rebuilds, mid-life overhauls)
"Old"	14 +	Moderate / Increasing	• Low annual mileage • Significant reduction in maintenance and rehabilitation activity (nearing retirement—allowed to deteriorate)

Between the ages of 5 and 14 (approximately), vehicles begin to undergo more or less continuous capital maintenance and rehabilitation—including engine and transmission rebuilds, upholstery replacement, exterior painting, and other component replacement activities. These capital maintenance activities occur regardless of whether there is an overhaul process or scheduled or unscheduled component replacements. Most agencies pursue these activities on an as-needed basis throughout this time period, with very few agencies conducting a more or less complete vehicle overhaul at a single point in time. Furthermore, the actual level of maintenance and rehabilitation pursued during this period varies widely across agencies.

During this period, a typical vehicle's overall condition rating will actually fluctuate up and down (e.g., pass above and then decay below the smoothed average line in Figure 6-3) as various rehabilitation activities are completed and the asset decay process begins again. Regardless of the level of rehabilitation pursued, these activities tend to reduce the rate of asset decay. At the same time, the level of annual service mileage derived from these vehicles tends to decrease over this period as operators focus service on newer fleet vehicles. The combined increase in rehabilitation activity and decrease in annual service miles serve to decrease the rate of vehicle decay. This emphasizes the necessity of rehabilitation activities, regardless of whether they are part of an overhaul program, scheduled in an organized replacement process, or completed as failures necessitate on an unscheduled basis (unusual). In addition, this pattern may support the exclusion of rehabilitation costs from a new federal reimbursable expense—an option that was considered in the initial hypotheses of potential service-life options.

Finally, most agencies begin to retire vehicles past the age of 12 or 14 years. As vehicles approach retirement, their annual miles of revenue service decrease significantly in favor of younger vehicles (tending to decrease the rate of asset decay). However, the value of fully maintaining a low-service vehicle approaching retirement declines continuously during this time period leading to significant reductions in rehabilitation activity and, consequently, a significant increase in the rate of vehicle decay. It should be noted, however, that several agencies operated vehicles in adequate (condition 3) or better condition well past the FTA's 12-year minimum retirement age. Service-life options in this extended-life time period (beyond 12 years) has very little interest based on historical usage experience.

Variation in Vehicle Decay Rates across Transit Agencies: 12-Year Vehicles

Figure 6-3 provides the upper and lower "bounds" demonstrating the (smoothed) average condition values for those sample agencies with the highest and lowest overall condition ratings. While these bounds do not fully explain the wide variation in 12-year vehicle conditions, they do point to significant differences in the rate of vehicle decay across U.S. transit operators (see Table 6-13).

Table 6-13
Average Number of Years to Attain Different Condition Ratings

Condition Rating	Years to Attain Condition Rating		
	Bottom Quartile Agencies	Average	Top Quartile Agencies*
5.0	0.0	0.0	0.0
4.5	1.0	1.2	1.4
4.0	2.0	2.4	2.9
3.5	3.3	4.0	7.0
3.0	5.1	8.4	13.5
2.5	13.6	15.7	NA
2.0	18.9	20.0	NA

*Note: None of the agencies with average fleet conditions ranking in the top quartile operated vehicles older than age 16.

For example, 12-year vehicles operated by the lowest ranked transit agencies typically decline from "Excellent" to "Good" (i.e., from condition rating 5 to 4) in only two years. However, for the highest ranked agencies, vehicles appear to decay more slowly and take an additional year to reach condition 4. Similarly, while vehicles operated by the lowest ranked operators typically take five years to decline to "Adequate" (condition 3), vehicles operated by the top ranked agencies do not attain this rating until after age 13, over one year past the FTA's minimum 12-year retirement age.

Implications for FTA's Minimum Service-life Policy: Part 2

The agency analysis presented above demonstrates that even the bottom quartile agencies can easily attain FTA's current 12-year minimum retirement age for 40-foot buses without concern for operating vehicles into the lower engineering condition values of 2.5 to 2.0. (As discussed above, an overall condition of 2.0 represents an overall vehicle condition that corresponds to the concept of a *maximum* retirement age or, better yet, a minimum acceptable service condition.) This implies that a lower minimum life option may not be necessary or appropriate, given the current bus design standards and operating conditions.

Correlation with Vehicle Life-Cycle Cost Analysis

Chapter 7 of this report reassesses the bus condition information considered here. There, the life-cycle cost analysis is used to identify financially optimal retirement ages for all transit bus and van vehicle types. The financially optimal retirement ages are then mapped to the corresponding expected physical condition for vehicles of the optimal retirement age. This correlation of engineering condition and life-cycle cost analyses is intended to provide an *absolute* answer to the optimal retirement age question (based on financial considerations) combined with an understanding of the *physical condition implications* of the identified optimal age (including expected levels of service reliability, service quality, and vehicle safety).

.

CHAPTER 7. LIFE-CYCLE COST ANALYSIS

This chapter presents the results of a minimum life-cycle cost analysis of the useful life of transit buses and vans. This analysis considers all of the capital or non-recurring costs associated with vehicle acquisition, as well as the recurring costs of vehicle operations, maintenance, and rehabilitation. The objective of this analysis is to identify the point in the asset life cycle at which total life-cycle costs are at their lowest or are “minimized.” From a financial perspective, the minimum life-cycle cost point represents the *optimal* vehicle retirement age. This minimum life-cycle cost analysis is presented first for the mainstay vehicle of the transit fleet—the 40-foot, heavy-duty, “12-year” bus. The process is then repeated for each of the other transit bus and van categories. Prior to presenting this analysis, the chapter first identifies several of the primary determinants to life-cycle costs and life expectancy (including annual vehicle mileage, average operating speed and agency rehabilitation practices) and then presents the full range of variation in these determinants across the nation’s bus transit operators.

Later, towards the end of the chapter, the results of the life-cycle cost analysis are combined with the vehicle physical condition analysis from the last chapter. The objective is to provide the reader with some understanding of a vehicle’s expected *physical* condition at the *financially* optimal retirement point (in other words, while the retirement point may be financially optimal, is the vehicle’s physical condition still acceptable to riders and operators?). Finally, this chapter concludes with an analysis of the potential loss of ridership and related fare revenues associated with increasing failure rates of an aging fleet. Together, the combined results of these differing analytical perspectives (cost, physical condition, and failure rates) help define the optimal useful-life periods for each bus and van vehicle category.

Data Sources and Caveats

The cost and timing of rehabilitation activities used for the analysis were obtained from agencies and vehicle manufacturers that participated in the interview process for this study. However, the response rate for the cost data portion of the interview guide was low, with few agencies responding fully. Additional cost data were obtained from prior studies including a 2002 Booz Allen Hamilton analysis of 30 small and medium-sized bus operators in Illinois. While the data obtained are of good quality and reported costs are comparable across all data sources, the overall sample size is small. Future life-cycle studies may wish to improve on the statistical reliability of the analysis by devoting additional resources to expanded data collection and a larger sample size. Data on the average annual vehicle mileages were obtained from NTD.

Key Determinants of Life-Cycle Costs

Life-cycle costs and vehicle life expectancy can vary significantly across transit operators, even for operators using the same vehicle type under similar vehicle maintenance regimes. Hence, it is important to consider these factors when conducting a life-cycle cost analysis intended to represent the experience of the nation’s transit operators as a whole. Towards this end, this section identifies three key determinants of vehicle life-cycle costs (and life expectancies)—

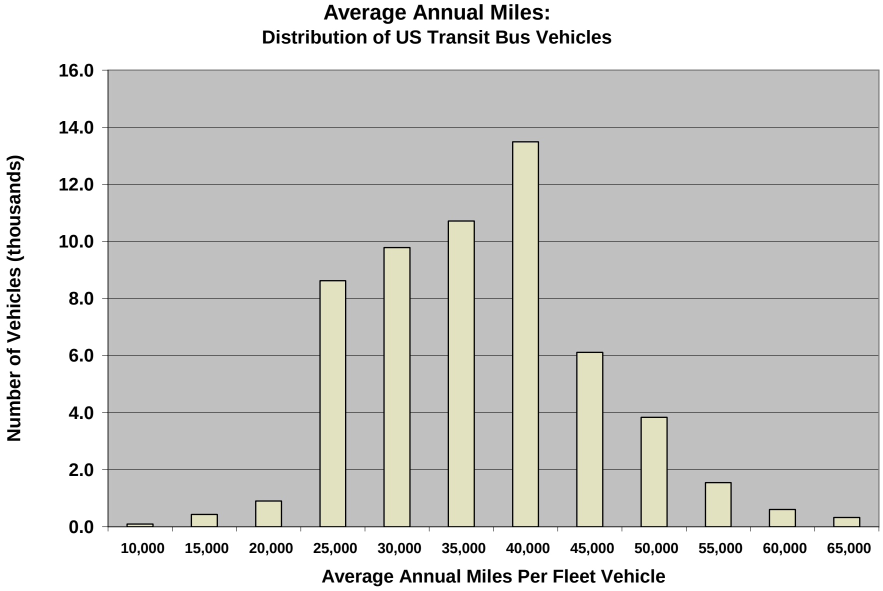
annual vehicle mileage, average operating speed, and agency rehabilitation practices. The section then goes on to discuss how these determinants vary across the nation's transit fleets, providing the full range of experience that needs to be reflected in the life-cycle cost analysis. The analysis here is focused on the 12-year vehicle type, but was also completed for the 10-, 7-, 5-, and 4-year vehicle categories (see below).

Fleet Operating Conditions: Annual Mileage and Operating Speed

The rate of vehicle wear is determined by a variety of factors including annual mileage, average operating speed, and passenger loadings. In general, higher annual mileages increase the rate of vehicle deterioration. Similarly, decreasing bus operating speeds are typically an indication of heavier duty-cycles (more frequent stops and starts) leading to a reduced life expectancy for drive trains, brakes, and other vehicle components. Variations in annual mileages and operating speeds also have an impact on both the timing of fleet rehabilitation activities (e.g., drive train replacements) and annual operating and maintenance costs (higher annual mileage vehicles generally require higher maintenance and consume more fuel per mile than lower mileage vehicles of the same age). Hence, an effective analysis of vehicle life-cycle costs must consider the range of annual mileages and service operating speeds experienced by U.S. transit operators.

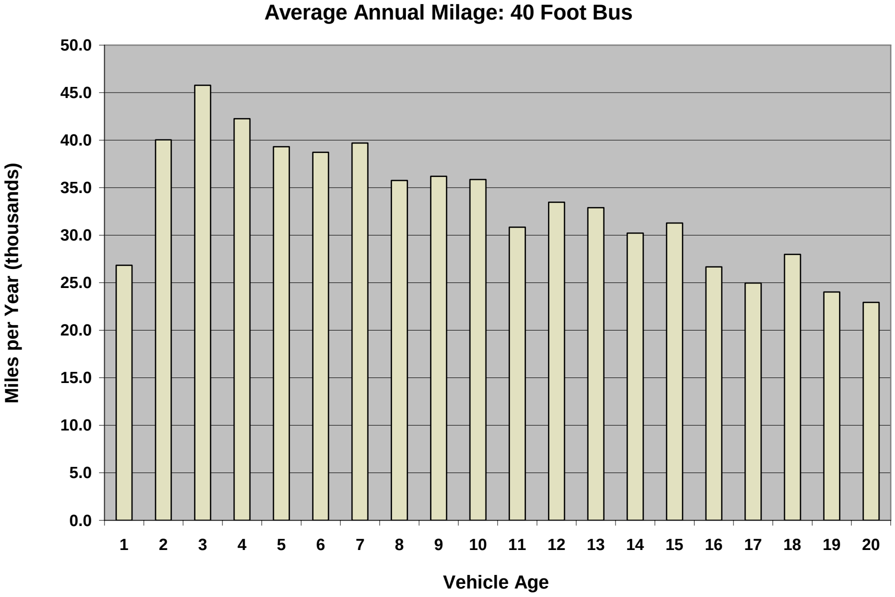
Figure 7-1 shows the distribution of annual vehicle mileages for 12-year transit buses based on 2004 NTD data. This chart shows a range of annual bus vehicle mileages, with most U.S. vehicles traveling between 25,000 and 45,000 miles each year. The average annual mileage across *all* of the nation's transit motor buses is just under 37,000 miles. The life-cycle cost analysis below will examine three specific annual vehicle mileage cases—25,000; 35,000; and 45,000 miles per year.

Figure 7-1



Average annual vehicle mileage tends to be highest during the earlier years of a vehicle's life (when utilization of the vehicle is highest), and then tends to decline as the vehicle ages (and is applied to lower demand routes). This characteristic is shown for the 12-year bus type in **Figure 7-2**. Once again, analysis of life-cycle costs needs to reflect natural variations in the rate of vehicle utilization throughout a vehicle's life to accurately determine the timing of rehabilitation activities.

Figure 7-2

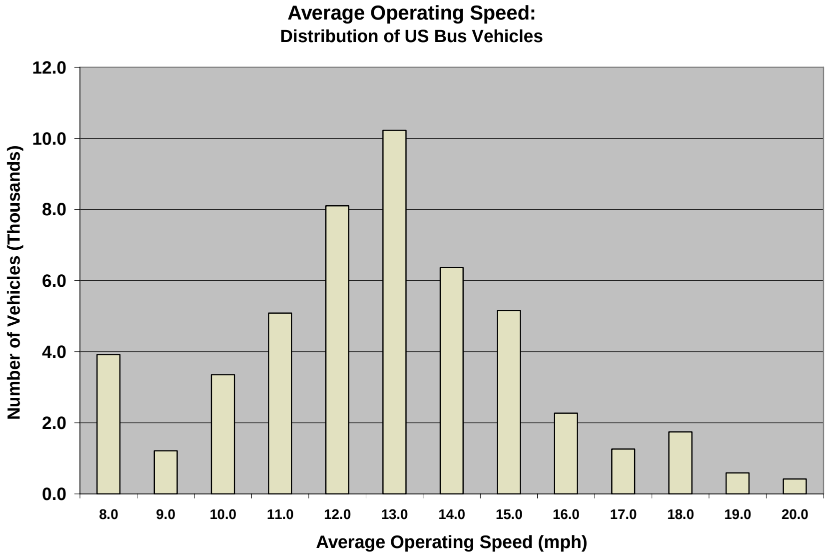


Finally, **Figure 7-3** shows the distribution of average operating speeds for 12-year transit buses. Based on this data, the average operating speed for 12-year transit buses is roughly 13 miles per hour with a range of between 8 and 20 miles per hour (although there is a small number of operators with average operation speeds outside of these boundaries). The life-cycle cost analysis presented below will utilize these minimum, maximum, and average operating speed values in defining the cost characteristics of the nation's fleets of 12-year vehicles. Similar bounds for annual vehicle mileage and operating speeds were developed for the life-cycle cost analyses of the 10-, 7-, 5-, and 4-year bus and van vehicle categories (see below). As noted earlier in this report, differences in average operating speed can be used as a proxy to account for differences in the total service *hours* (and the condition impacts of differences in hours) of transit vehicles with similar life-to-date service miles. (Note: Agencies can and do measure life-to-date vehicle *mileage* but currently have no means to measure life-to-date *hours*.)

Fleet Rehabilitation Practices

In addition to variations in annual vehicle mileages and mean operating speeds, transit agencies also employ differing life-cycle vehicle rehabilitation practices for their fleets. This analysis will consider two specific cases. The first case considers those agencies that undertake an extensive mid-life overhaul of their fleet vehicles. In addition to the typical drive train replacement (engine and transmission replacement, occurring every 250,000 miles on average), extensive overhauls also include some body work, exterior repainting, replacement of most or all interior upholstery, window and floor replacements, technology upgrades, etc. The practice of conducting major mid-life overhauls is typically confined to the nation's largest and highest ridership bus operators (e.g., New York City Transit, New Jersey Transit, and WMATA), but is relatively uncommon for most other operator sizes. Where utilized, major mid-life overalls of 12-year vehicles typically occur when the vehicle is six to seven years in age and are expected to provide several years of additional service life.

Figure 7-3



The second case considered here is intended to represent those operators that do not perform a major, coordinated mid-life overhaul (most of the nation's bus operators and roughly three-quarters of the nation's bus vehicle fleet). For these operators, replacement and rehabilitation of worn vehicle components is an ongoing, continuous process performed on an as-needed basis. In reality, there is likely a continuum of rehabilitation practices between these two extremes. However, examination of these two limiting cases will effectively convey the relevant range of life-cycle cost issues between them.

Life-Cycle Cost Analysis

The preceding analysis is intended to provide an understanding of the range of operating characteristics and rehabilitation practices that together are believed to drive differences in life-cycle costs and vehicle life expectancy across the nation's transit operators. Using that analysis, this section develops a detailed life-cycle cost analysis of the 12-year, 40-foot vehicles that constitute the bulk of the nation's bus transit fleets. This analysis is then used to identify that point in the vehicle life cycle when the sum total of all annualized costs (capital, operating, maintenance, and rehabilitation) is minimized. This minimum life-cycle cost point represents a financially optimal age to retire and replace a vehicle, in effect providing a measure of "economic useful life" (as distinguished from an engineering useful life or other measure). As expected, the point at which life-cycle costs are minimized can vary appreciably given differences in annual mileages, average operating speeds, and rehabilitation practices.

Specifically, this analysis considers the following life-cycle costs:

- **Acquisition Cost and Disposal Value:** This includes purchase cost plus related procurement costs as well as the expected sale price or scrap value of the used vehicle.
- **Expected Component Replacements and Mid-Life Overhaul Costs:** This includes the cost of all expected component replacements and rebuilds naturally occuring over the life of a vehicle (e.g., drive train rebuild) as well as the cost of any additional planned mid-life overhaul activities (if any). These costs are oriented toward the larger component replacement, rebuild, or rehabilitation needs and exclude the cost of minor vehicle repairs. Examples include:
  - Engine and transmission rebuilds
  - Other expected component replacements (e.g., brakes, tires, batteries, suspension, etc.)
  - Mid-life overhaul costs (e.g., repainting; replacement of flooring, upholstery, windows; body work; etc.)
- **Operating and Maintenance Costs**: This includes the cost of fuel, preventative maintenance programs, and all labor and parts for minor repairs as required to maintain vehicles in good working order.

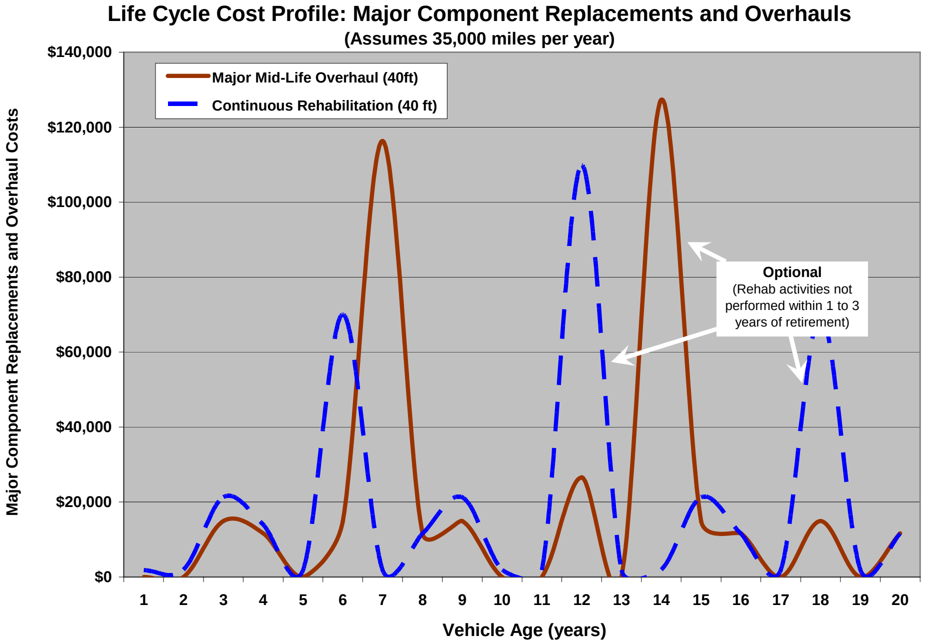
The following sub-sections provide an analysis of the expected annual cost of these different cost types throughout the vehicle life cycle, beginning with a discussion of expected component replacement and mid-life overhaul costs.

Expected Component Replacement and Mid-Life Overhaul Costs

Figure 7-4 presents the distribution of expected major component replacement and mid-life overhaul costs over a potential 20-year life cycle for a 40-foot transit bus (hence it excludes the cost of vehicle acquisition and all other vehicle operating and maintenance costs). The chart assumes a vehicle that averages 35,000 miles per year over the full life cycle. The chart also considers the two cases of: (1) those agencies that complete an extensive mid-life overhaul and (2) those agencies that do not complete a mid-life rebuild but carry out their major component replacements on a continuous, as-needed basis. The analysis also assumes that the number of times a given replacement/rebuild activity is performed depends on the vehicle's age at the time of retirement. For example, if engine rebuilds occur on roughly a six-year cycle (every 210,000 miles), then this activity will occur once for a vehicle retired before 12 years, twice for a vehicle retired before 18 years, and 3 times for a vehicle retired at age 20 or later. Similarly, it is assumed that agencies currently pursuing a major mid-life rebuild program at vehicle age 7 (for example) would want to repeat the process again at age 14 if the vehicle was expected to operate well past that age.

In reviewing Figure 7-4, it is easy to identify the timing of major vehicle replacement activities. In particular, the timing of the 7-year major mid-life overhaul (and its potential repetition at age 14) stands out clearly. These investments include the cost of engine and transmission rebuilds, repainting, significant rehab and replacement of vehicle interiors (flooring, upholstery, and windows), bodywork as needed, some electrical work, and other upgrades. In contrast, the mid-life peaks for those agencies that do not perform a major mid-life overhaul are significantly lower (fewer rehab activities equate to lower costs) but also have higher cost peaks for the intervening years (as some replacement activities tend to be more spread out). The smaller peaks primarily represent replacement of those components having shorter expected lives including tires, brakes, and batteries.

Figure 7-4



From the viewpoint of evaluating FTA's service-life policy, the key point to note is that, whether or not an agency conducts a major mid-life overhaul, there are major cost cycles that are repeated throughout a vehicle's life cycle, which are roughly concurrent with drive-train rebuilds (e.g., the cost peaks at roughly ages 6 to 7 and 12 to 14 in Figure 7-4). These major cycles help guide agency rehab-replacement decisions—specifically, agencies will only complete a major vehicle rehabilitation initiative if they intend to keep that vehicle in service for at least three to five years after these improvements have been made. For example, in the case of a heavy-duty vehicle approaching 12 years in age, an agency will only reinvest in that vehicle (e.g., rebuild/replace the engine and transmission) if the agency intends to obtain an additional three to five years of revenue service from that vehicle. Otherwise, these rehabilitation activities will be avoided (to save cost) and the vehicle will be retired *after* the minimum retirement requirements have been satisfied. To summarize, vehicle rehab and replacement decisions are determined by the timing of the vehicle's major reinvestment cycles, with the timing of these cycles determined by annual vehicle mileage, average operating speed and environment, and agency maintenance practices.

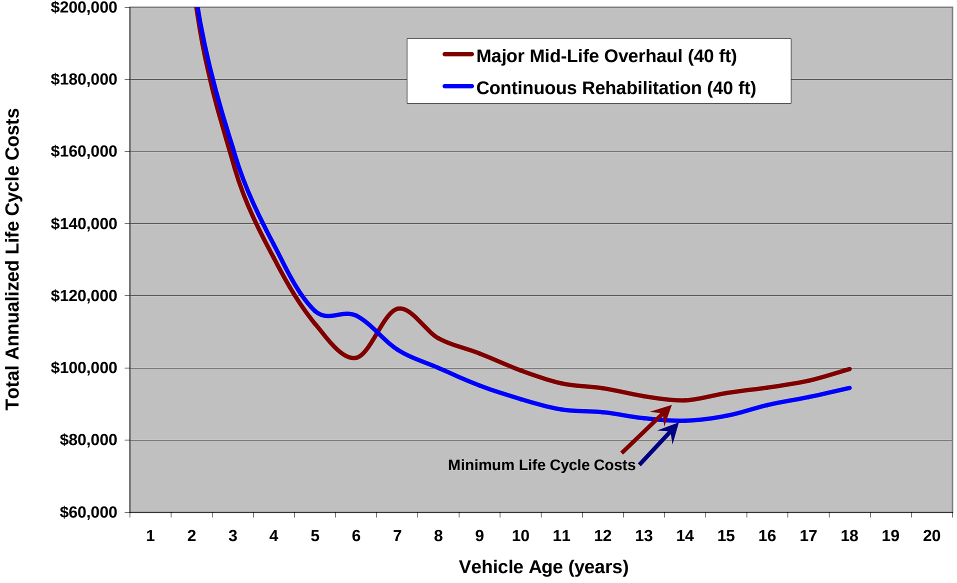
Minimum Life-Cycle Cost Analysis

Figure 7-4 above profiles the expected annual expenditures on component replacements and mid-life overhaul activities for heavy-duty vehicles for each year in the asset life cycle (including several years beyond the industry average retirement ages). In contrast, the objective of this analysis is to identify that point in the asset life cycle at which the annualized value of all life-cycle costs—including acquisition costs, component replacement costs, mid-life overhaul costs, and operations and maintenance (O&M) costs—are minimized. This minimum life-cycle cost analysis is depicted graphically in **Figure 7-5**. Specifically, the cost values in this chart provide a measure of the average cost of ownership for a 40-foot vehicle at each vehicle age.[7] For example, if a heavy-duty vehicle were retired at age 5, the annualized cost would be roughly $115,000 (at that point, regardless of whether the owner agency performs a mid-life rehab or not). Somewhere between the ages of 8 and 10, this annualized cost drops below $100,000, reaching a cost minimum around a vehicle age of 14.

Figure 7-5

Minimum Life Cycle Cost Profiles: Including Vehicle Acquisition, Major Component Replacement, Overhaul, and O&M Costs

(Assumes 35,000 miles per year)



The determinants for the shape of the cost curve in Figure 7-5, including the “U” shaped minimum, are as follows. First, as the number of years of ownership increase, a vehicle’s acquisition cost becomes spread over an increasing number of years, thus reducing the average annualized *capital* cost of ownership. It is this decreasing annualized capital cost (the largest of all vehicle life-cycle costs), that accounts for the downward sloping curve through age 14. At the same time, increasing vehicle age is also accompanied by increasing operating and maintenance costs (vehicles require more frequent repairs as they age), an effect that is captured by the slow rise in costs that becomes apparent in this chart after vehicle age 14. (Note: At age 14 in this chart, the savings from spreading capital costs over a greater number of service years is overtaken by the increase in annual O&M costs.) Together, the combined impacts of decreasing annualized capital costs and increasing operating costs as vehicle age increases, yields a “U” shaped curve with a cost minimum. Finally, the bumps in this curve around ages six and seven

---

[7] *More precisely, annualized cost is not the actual cost divided by the number of years of service (e.g., acquisition cost / vehicle age). Rather, annualized cost represents the stream of annual payments the net present value of which are equivalent to the initial investment cost. Specifically, the annualized cost of the vehicle acquisition cost for any age is given by* $\left(Acquisition\ Cost\right)*\left(i/\left(1-(1+i)^{-(Vehicle\ Age)}\right)\right)$.

capture the cost of major component replacement and overhaul activities (e.g., drive train replacement), costs that become less apparent at later vehicle ages as they are also spread over an increasing number of years of service.

This brief discussion is intended to provide a high-level overview of the application of minimum life cycle analysis to transit buses and vans. A more detailed explanation and analysis can be found in Appendix D (minimum life-cycle cost methodology), Appendix E (details of the life-cycle cost analysis for heavy-duty vehicles), and Appendix F (transit vehicle life-cycle cost data).

Minimum Life-Cycle Cost Analysis Results: 40-Foot Buses

The results of the minimum life-cycle cost analysis for 40-foot, heavy-duty buses is presented in **Table 7-1**. Each row provides the age and mileage at which the minimum life-cycle cost point is reached depending on (1) the average annual vehicle mileage and (2) whether or not the vehicle undergoes agency performs a major mid-life overhaul (versus “continuous rehabilitation”). For each of these six cases, the minimum life-cycle cost is attained at or after the current FTA 12-year minimum (see below). For the single case where the cost minimum occurs right at the 12-year age (i.e., vehicles with 45,000 annual miles), the cost minimum is attained at 540,000 miles, thus exceeding the 500,000-mile minimum requirement. Recall here that the average annual vehicle mileage for 40-foot buses is just over 35,000 miles.

Table 7-1
Minimum Life-Cycle Cost Replacement Ages:
40-Foot, 12-Year/500,000-Mile Bus

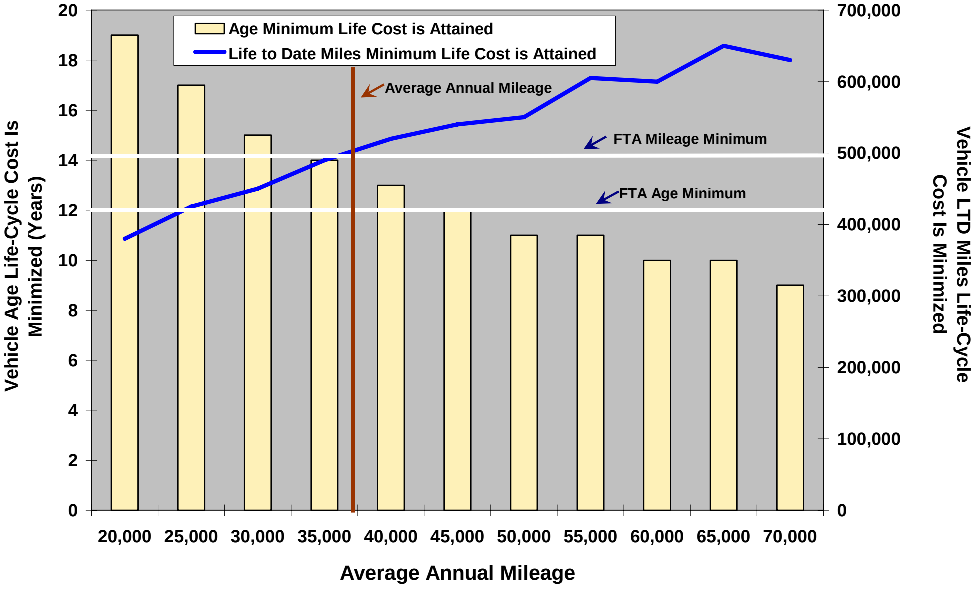
Annual Vehicle Mileage	Agency Performs: Major Mid-Life Overhaul		Agency Performs: Continuous Vehicle Rehabilitation	
	Minimum Life-Cycle Cost Age	Minimum Life-Cycle Cost Mileage	Minimum Life-Cycle Cost Age	Minimum Life-Cycle Cost Mileage
25,000	16	400,000	17	425,000
35,000	14	490,000	14	490,000
45,000	12	540,000	12	540,000

The analysis in Table 7-1 considers the minimum life-cycle cost for three specific annual vehicle mileages—25,000; 35,000 (the national average); and 45,000 annual vehicle miles. **Figure 7-6** provides the ages and life-to-date mileages at which life-cycle costs are minimized for vehicles traveling between 20,000 and 70,000 miles annually. The solid bars and left-side axis present the ages at which life-cycle costs are minimized for this range of annual vehicle mileages. The solid line and right-hand axis present the life-to-date mileages at which life-cycle costs are minimized.

Review of Figure 7-6 suggests that, from a cost-effectiveness perspective, FTA’s current retirement minimums (for large buses) of 12 years or 500,000 miles represent reasonable choices. For ***all*** annual vehicle mileages, the minimum cost point is attained at either an age or mileage that exceeds one or both of the FTA minimums for these measures. In all cases, the difference between one and both of the current FTA minimum requirements also provides some margin for the early retirement of vehicles with reliability problems. For example, vehicles traveling an average of 40,000 miles per year could reach their cost minimums at age 13 and a LTD (life to date) mileage of 520,000 miles. Hence, this provides a "margin" of one year or 20,000 miles of optimal service beyond the FTA minimum for an average vehicle or the option to reduce service life by these amounts for less reliable vehicles. Moreover, this difference between the 12-year and 500,000-mile minimum is smallest (while still providing a meaningful early retirement margin) for vehicles that average between 30,000 and 45,000 miles of travel per year. Together, these vehicles account for more than 70 percent of the nation's large buses.

Figure 7-6

Age and Mileage at Which Life-Cycle Cost Is Minimized
(Single Mid-Life Rehabilitation or Single Drive Train Replacement)



Other Bus and Van Types

The preceding analysis has focused entirely on the life-cycle cost attributes of a standard 12-year, 40-foot bus. This section provides a summary analysis of all remaining bus and van types (with their current FTA retirement minimums) including:

- Articulated buses (12-year; 500,000-LTD-mile minimum)
- Heavy-duty, small buses (10-year; 350,000-LTD-mile minimum)
- Medium-duty, small buses (7-year; 200,000-LTD-mile minimum)
- Light-duty, mid-size buses and vans (5-year; 150,000-LTD-mile minimum)
- Light-duty, small buses and vans (4-year; 100,000-LTD-mile minimum).

This analysis is founded on both data collected for this study as well as data available from similar analyses (including an analysis of small and medium-sized bus operators located in downstate Illinois). Again, while these data sources have provided good, quality vehicle purchase and rehabilitation cost data, the sources lack depth. It is recommended that future useful-life studies devote increased resources to ensure a more robust data sample.

Articulated Buses

Table 7-2 presents the ages and LTD mileages at which life-cycle costs for articulated buses reach their minimum. Here, each row provides the age and mileage at which the minimum life-cycle cost point is reached depending on the average annual vehicle mileage and on whether or not the agency performs a major mid-life overhaul (versus "continuous rehabilitation"). Overall, the minimum cost ages and mileages as well as the optimal overhaul/rebuild assumptions are the same for articulated buses as that found for 40-foot buses.

Table 7-2
Articulated Bus (60 Foot) – Minimum Life-Cycle Cost Replacement Ages

Annual Vehicle Mileage	Agency Performs: Major Mid-Life Overhaul		Agency Performs: Continuous Vehicle Rehabilitation	
	Minimum Life-Cycle Cost Age	Minimum Life-Cycle Cost Mileage	Minimum Life-Cycle Cost Age	Minimum Life-Cycle Cost Mileage
25,000	19	475,000	17	425,000
35,000	14	490,000	14	490,000
45,000	12	540,000	12	540,000

Figure 7-7

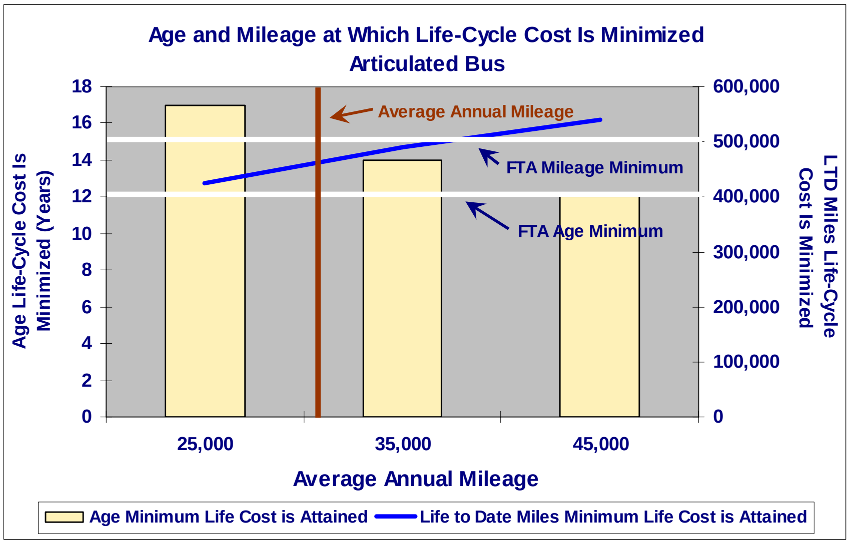


Figure 7-7 charts the results from Table 7-2 along with the current FTA minimum age and mileage requirements. This chart suggests that FTA's current age and mileage minimums are appropriate when assessed from the viewpoint of minimizing total life-cycle costs. This is based on the fact that: (1) all vehicles, regardless of annual average mileage, attain their minimum life-cycle point at an age or LTD mileage that exceeds the existing FTA minimums and (2) in all

cases, the current FTA age and mileage minimums provide a margin for early retirement of problem vehicles (i.e., vehicles with above average expenses and/or reliability issues). Note that the national average annual mileage for U.S. articulated buses is 31,900 miles per year.

Heavy-Duty, Small Buses (10-year; 350,000-LTD-mile minimum)

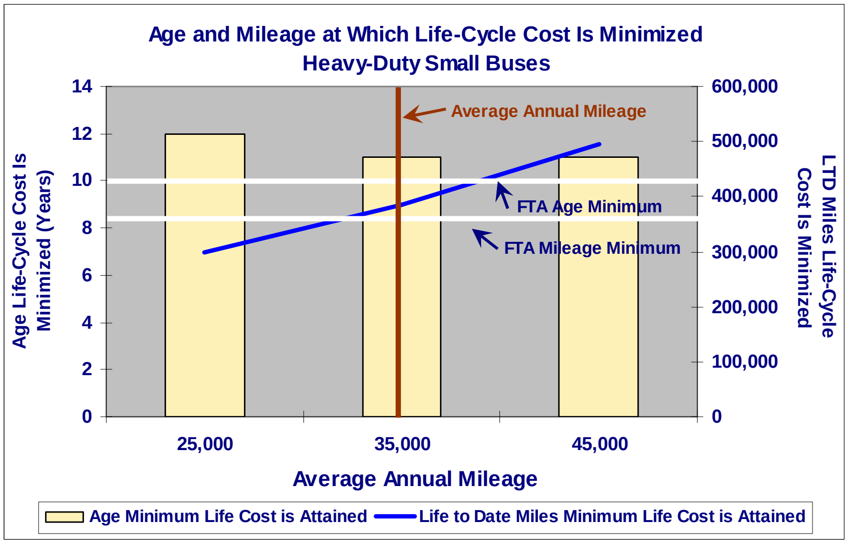
Table 7-3 presents the ages and LTD mileages at which life-cycle costs for small, heavy-duty buses reach their minimum**.** Similarly, **Figure 7-8** charts the results from Table 7-3 along with the current FTA minimum age and mileage requirements. This analysis again suggests that FTA's current age and mileage minimums are appropriate when assessed from the viewpoint of minimizing total life-cycle costs. Again, all vehicles, regardless of annual average mileage, attain their minimum life-cycle point at an age and/or LTD mileage that exceeds the existing FTA minimums, and in all cases, the current FTA age and mileage minimums provide a margin for early retirement of problem vehicles. The national average annual mileage for U.S. heavy-duty, small buses is 35,400 miles per year.

Table 7-3
10-Year, Heavy-Duty, Small Bus –
Minimum Life-Cycle Cost Replacement Ages

Annual Vehicle Mileage	Agency Performs: Continuous Vehicle Rehabilitation		
	Minimum Cost Age	Minimum Cost Mileage	Full Drive Train Replacement?*
25,000	12	300,000	No
35,000	11	385,000	Yes
45,000	11	495,000	Yes

* The analysis selects the minimum cost age and mileage for that drive train replacement option (i.e., replace or do not replace) that provides the lowest minimum total life-cycle cost.

Figure 7-8



Medium-Duty, Small Buses (7-year; 200,000-LTD-mile minimum)

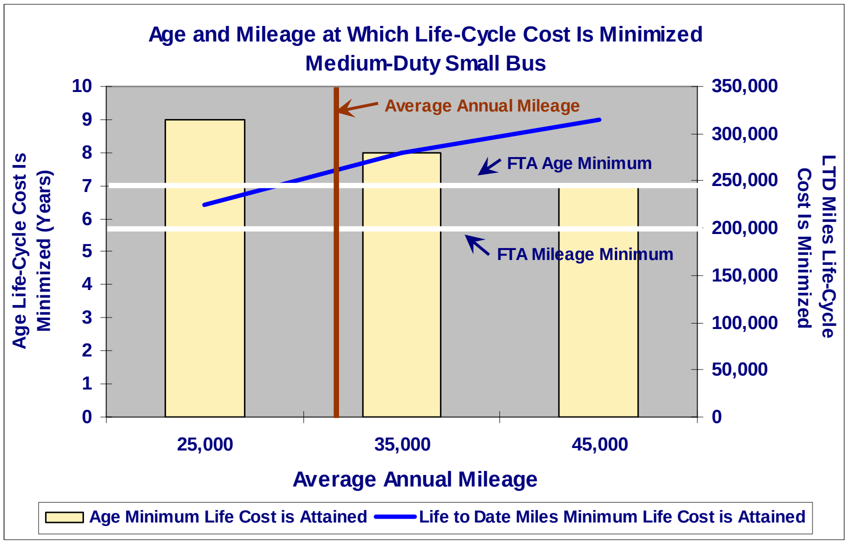
Table 7-4 presents the ages and LTD mileages at which life-cycle costs for small, medium-duty buses reach their minimum, while **Figure 7-9** charts these results along with the current FTA minimum age and mileage requirements. As with the larger vehicle types, this analysis finds that: (1) all vehicles, regardless of annual average mileage, attain their minimum life-cycle point at an age and/or LTD mileage that exceeds the existing FTA minimums, and (2) in all cases, the current FTA age and mileage minimums provide a margin for early retirement of problem vehicles.

Table 7-4
7-Year, Medium-Duty, Small Bus –
Minimum Life-Cycle Cost Replacement Points

Annual Vehicle Mileage	Agency Performs: Continuous Vehicle Rehabilitation		
	Minimum Cost Age	Minimum Cost Mileage	Full Drive Train Replacement?*
25,000	9	225,000	No
35,000	8	280,000	Yes
45,000	7	315,000	Yes

* The analysis selects the minimum cost age and mileage for the drive train replacement option (i.e., replace or do not replace) that provides the lowest minimum total life-cycle cost.

Figure 7-9



One difference here is the fact that minimum life-cycle cost points for all three of the annual vehicle mileage groupings considered here (25,000; 35,000; and 45,000 miles per year) meet or exceed *both* the current FTA minimum age requirement and the current minimum LTD mileage requirement. Despite this observation, there does not appear to be significant justification for revising the existing FTA minimums (i.e., using minimum life-cycle cost as a criterion). The national average annual mileage for medium-duty, small buses is 32,800 miles per year.

Light-Duty, Mid-Size Buses and Vans (5-year; 150,000-LTD-mile minimum)

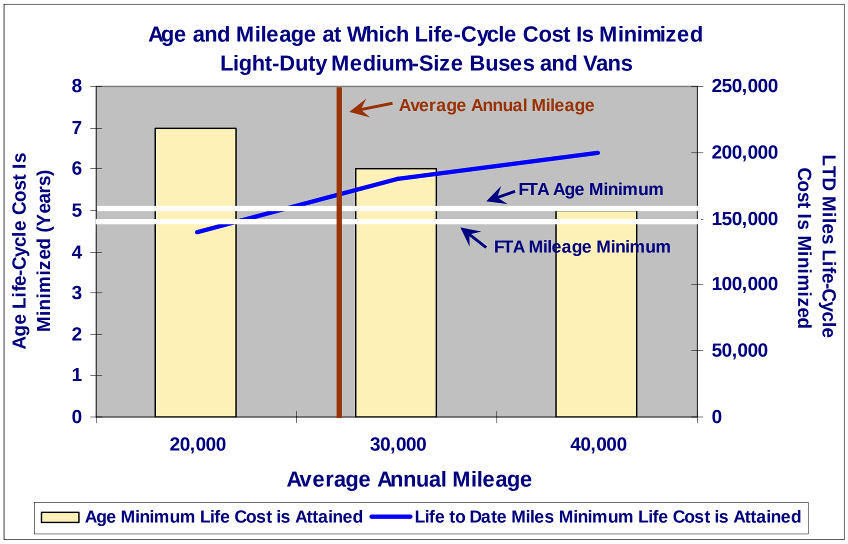
Table 7-5 presents the ages and LTD mileages at which life-cycle costs for light-duty, mid-size buses and vans reach their minimum, while **Figure 7-10** charts the results for these vehicles along with their current FTA minimum age and mileage requirements. (Note here that the annual vehicle miles of travel groupings have all dropped by 5,000 miles as compared to the prior charts, reflecting the lower average annual mileages for light-duty vehicle types.)

Table 7-5
5-Year, Light-Duty, Mid-Size Buses and Vans – Minimum Life-Cycle Cost Replacement Points

Annual Vehicle Mileage	Agency Performs: Continuous Vehicle Rehabilitation		
	Minimum Cost Age	Minimum Cost Mileage	Full Drive Train Replacement?*
20,000	7	140,000	No
30,000	6	180,000	No
40,000	5	200,000	No

* This analysis selects the minimum cost age and mileage for the drive train replacement option (i.e., replace or do not replace) that provides the lowest minimum total life-cycle cost.

Figure 7-10



As before, this analysis finds that: (1) all vehicles, regardless of annual average mileage, attain their minimum life-cycle point at an age and/or LTD mileage that exceeds the existing FTA minimums, and (2) in all cases, the current FTA age and mileage minimums provide a margin for early retirement of problem vehicles. Compared to the vehicle types considered above, one difference here is that the minimum cost ages and mileages for all vehicle types (based on this analysis) are associated with the scenario where there is no engine replacement over the life of the vehicle (in contrast, for the vehicle types considered above, the lowest life-cycle cost points for vehicles with average and higher annual mileages were associated with the full drive-train replacement option). The national average annual mileage for light-duty, mid-size buses and vans is 29,500 miles per year.

Light-Duty, Small Buses and Vans (4-year; 100,000-LTD-mile minimum)

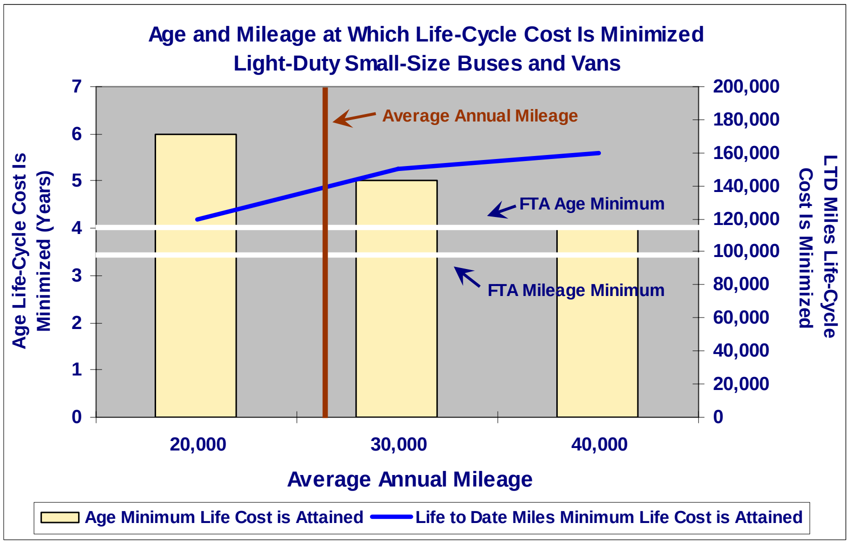
Table 7-6 presents the ages and LTD mileages at which life-cycle costs for light-duty small buses and vans reach their minimum, while **Figure 7-11** charts this information along with the FTA minimum age and mileage requirements. Again, this analysis finds that: (1) all vehicles, regardless of annual average mileage, attain their minimum life-cycle point at an age and/or LTD mileage that exceeds the existing FTA minimums, and (2) in all cases, the current FTA age and mileage minimums provide a margin for early retirement of problem vehicles. Each of the three vehicle mileage examples (20,000; 30,000; and 40,000 per year) has minimum life-cycle cost mileages that exceed the FTA minimum retirement requirement of 100,000 LTD miles. The national average annual mileage for light-duty, small buses and vans is 28,500 miles per year.

Table 7-6
4-Year, Light-Duty, Small Buses and Vans –
Minimum Life-Cycle Cost Replacement Points

Annual Vehicle Mileage	Agency Performs: Continuous Vehicle Rehabilitation		
	Minimum Cost Age	Minimum Cost Mileage	Full Drive Train Replacement?*
20,000	6	120,000	No
30,000	5	150,000	No
40,000	4	160,000	No

* This analysis selects the minimum cost age and mileage for that drive-train replacement option (i.e., replace or do not replace) that provides the lowest minimum total life-cycle cost.

Figure 7-11



Life-Cycle Cost Analyses of Changes to FTA's Service-life Policy

In addition to identifying the financially optimal retirement point for each bus and van category, a related study objective was to consider other potential financial implications of or changes to FTA's minimum service-life policy. Specifically, this includes finding answers to the following questions:

- How would an increase or decrease in FTA's minimum service-life requirements impact transit industry finances, including annual replacement expenditures and agency operating costs?
- How does the continuing addition of new technologies affect the financially optimal useful life?

The following sub-sections consider each of these questions.

Financial Impacts of More and Less Frequent Bus Replacement: Industry Perspective

This sub-section seeks to answer the first question from the perspective of the transit industry as a whole. Specifically, how would an increase or decrease in FTA's minimum service-life requirements affect vehicle replacement at the industry level? The analysis first considers the case of a two-year reduction in the FTA minimum service-life requirements for large, heavy-duty, buses (i.e., from 12 to 10 years), and then repeats this analysis for a two-year increase in the minimum age requirements for that vehicle type (from 12 to 14 years). The impact of these changes from the agency perspective is considered in the next sub-section.

Reduction in Minimum Life from 12 to 10 Years

As discussed in prior sections of this report, very few of the nation's transit operators are likely to reduce their current vehicle retirement ages if FTA were to reduce the current retirement minimums by one or two years. This is because the vast majority of the nation's operators retire their heavy-duty buses two to four years after the retirement minimums have been reached due to financial constraints. Hence, any reduction in FTA's minimum useful life would only impact those few operators whose retirement decisions are in fact constrained by the existing service-life policy, and the resulting industry-wide cost impact of that change would be very small.

To emphasize this point, refer back to Figure 4-1. Based on the analysis presented there, roughly 6 percent and potentially as much as 10 percent of all retirements for heavy-duty buses occur right at vehicle age 12. This translates to an average of roughly 200 to 300 vehicle retirements per year for which the time of retirement is potentially constrained by FTA's minimum life requirements. Suppose now that the minimum retirement age for heavy-duty buses was reduced two years (i.e., from 12 to 10 years). Assuming that *all* vehicles currently retired right at the current 12-year minimum shifted to the new 10-year minimum (an unlikely event as some of these operators will also face funding constraints or state and local minimum life requirements), then the long-term average annual replacement rates for these operators would increase from 200 to 300 vehicles annually to 240 to 360 vehicles annually, an increase of 40 to 60 additional vehicles per year.[8] Given that deliveries of new buses have averaged roughly 3,000 per year over the past decade, and the industry's estimated total vehicle production capacity of 7,500 to 10,000 vehicles, the addition of 40 to 60 additional new vehicles resulting from a two-year reduction in the heavy-duty vehicle minimum life requirement is far from significant.

Increase in Minimum Life from 12 to 14 Years

In contrast, an increase in the minimum retirement age would force about 825 annual vehicle retirements (roughly 20 percent of the total) to be postponed by one or two years. Assuming that all vehicles currently retired at age 12 or 13 would now be retired at the new 14-year minimum, the long-term average annual replacement rates for these operators would decrease from roughly 825 vehicles annually to roughly 700 vehicles annually, a decrease of 125 vehicles per year.[9] Once again, the impact of this change on an industry that delivers roughly 3,000 per year is not significant. It is critical to understand, however, if the minimum life were extended past 14 years of age (e.g., to ages 15, 16 or more), the impact on the industry would quickly become very significant, particularly for vehicle manufacturers.

Financial Impacts of More and Less Frequent Bus Replacement: Agency Perspective

Consider the impact now from the viewpoint of an individual transit operator that currently retires its vehicles at 12 years of age and would reduce that retirement age to 10 years if permitted by FTA policy. Here, earlier vehicle retirement would increase that agency's vehicle-related capital costs but would also reduce the agency's operating costs (as newer vehicles require less maintenance). What then would be the net impact of this two-year reduction in FTA's replacement age minimum for operators of this type? **Table 7-7** answers this question using the life-cycle cost analysis discussed in the preceding sections of this chapter. Specifically, this analysis shows the annualized costs of capital and major component replacement costs and operating and maintenance costs for retirement at ages 12 and 10, and the differences in these costs. As expected, earlier retirement increases annualized capital and component costs and decreases annualized operating costs. The net impact is a $3,600 *increase* in annualized costs from retiring at age 10 versus age 12. Roughly speaking, this implies that the total annual cost of vehicle operations—including capital, major component replacement and O&M costs (and taking discounting into effect)—would be roughly $3,600 higher for agencies retiring their vehicles at age 10 than for those retiring their vehicles at age 12. This amounts to more than a four percent increase in annual vehicle-related costs.

---

[8] *This analysis excludes the initial "bump" in vehicle replacements of roughly 400 to 600 vehicles that would occur in the first year the policy took effect.*

[9] *This analysis excludes the initial postponement of roughly 800 or more vehicles that would occur in the first two years the policy took effect.*

Table 7-7
Annualized Vehicle Costs – Large, Heavy-Duty Bus:
Per Vehicle Impact of Reducing Vehicle Retirement Age from 12 to 10 Years

Cost Element	Annualized Costs for Retirement at:		
	Age 12	Age 10	Change
Capital Costs and Major Component Replacement Costs	$60,700	$66,300	+ $5,600
Operating and Maintenance Costs	$27,000	$25,000	- $2,000
Total	$87,700	$91,300	+ $3,600

Assumes vehicle averaging 35,000 miles per year.

What then would be the impact of increasing the minimum retirement age for heavy-duty vehicles from 12 to 14 years (for example)? The answer to this question is addressed in **Table 7-8**. Later retirement decreases annualized capital and component costs and increases annualized operating costs. The net impact is a $2,800 *decrease* in annualized costs from retiring at age 14 versus age 12. Roughly speaking, this implies that the total annual cost of vehicle operations would be roughly $2,800 lower for agencies retiring their vehicles at age 14 than for those retiring their vehicles at age 12. This amounts to more than a three-percent drop in annual vehicle-related costs.

Table 7-8
Annualized Vehicle Costs – Large, Heavy-Duty Bus:
Per Vehicle Impact of Increasing Vehicle Retirement Age From 12 to 14 Years

Cost Element	Annualized Costs for Retirement at:		
	Age 12	Age 14	Change
Capital Costs and Major Component Replacement Costs	$60,700	$55,700	- $5,000
Operating and Maintenance Costs	$27,000	$29,200	+ $2,100
Total	$87,700	$84,900	- $2,800

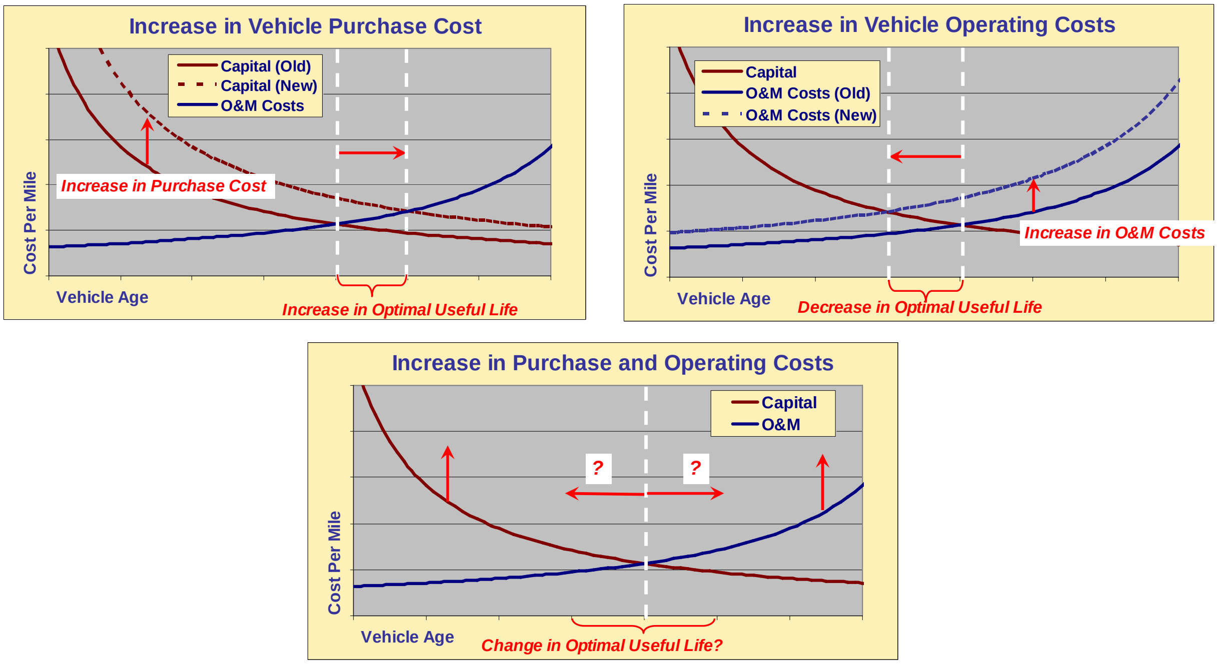
Assumes vehicle averaging 35,000 miles per year.

Impact of New Bus Technologies on the Financially Optimal Retirement Age

The next question to be addressed is: How does the continuing addition of new technologies affect the financially optimal useful life? In considering this question, it is important to understand that any increase in vehicle capital costs will tend to increase the financially optimal retirement age, while any increase in operating and maintenance costs will tend to decrease the optimal retirement age. The net change depends on which of these two impacts is larger. This interaction is presented in **Figure 7-12**.

With respect to new technologies such as AVL, APCs, voice annunciation, security cameras, and collision avoidance systems, the increase in vehicle purchase price is dependent on which specific technologies are included in a new bus specification. Adding most or all of these components can be expected to increase the price of the bus by roughly $30,000 to $50,000. Assuming these technology components have life cycles comparable to that of the bus itself yields a roughly 10-percent to 15-percent increase in the annualized vehicle capital cost. In the absence of any change to operating costs, the life-cycle analysis shows that this increase does ***not*** impact the optimal vehicle retirement age. In fact, vehicle capital cost needs to increase by up to \$200,000 to alter the financially optimal retirement age by even one year (upward)[10].

Figure 7-12
Impact of Changes in Capital and Operating Costs on Minimum Life-Cycle Cost



Similarly, operators investing in these new technologies now anticipate increased costs to maintain these new systems (either directly by operator staff or through vendor maintenance agreements). Even if it is assumed that these costs add 20 percent to annual vehicle O&M costs (a rather conservative assumption), there is still no impact on the optimal retirement ages identified earlier in this chapter. However, the key unknown in this analysis is how these operating costs change with time. Most agencies anticipate that these new technologies will begin to fail at an increasing rate as the vehicle approaches 12 or more years of revenue service. With multiple systems in place, these failures may have significant impacts on an agency's ability to make their peak-period pullout requirements. However, none of these systems has been in place for a sufficiently long time to have reliable cost data for these systems at the more advanced bus ages (i.e., age 12 or higher). It can be noted, however, that based on the cost analysis performed for this study, vehicle O&M costs would need to increase by more than one-third before the cost impact of these new technologies would alter the financially optimal retirement age by even one year (downward).

---

[10] *This because of the very flat shape of the annualized capital cost curve.*

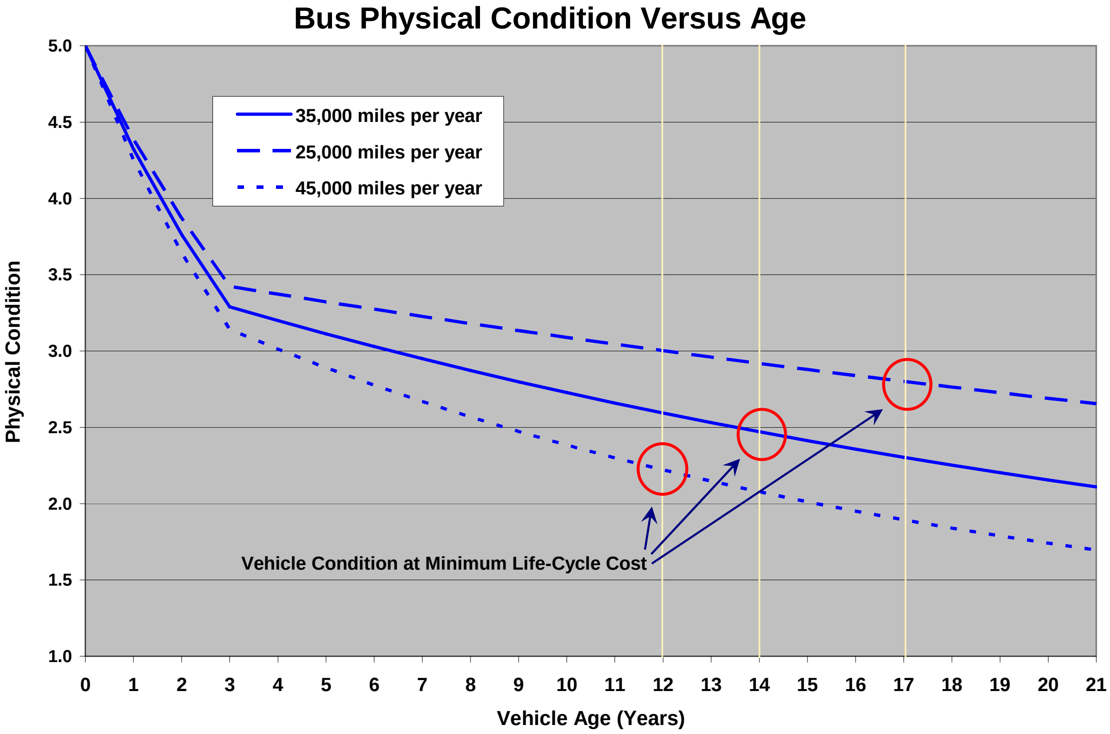
Vehicle Physical Condition versus Minimum Cost Retirement Age

Heavy-Duty, Large Buses

The analysis above considers the point in the asset life cycle at which annualized life-cycle costs are minimized. This provides an assessment of useful life based entirely on cost effectiveness, and hence without reference to vehicle condition or quality of service. In contrast to this approach, **Figure 7-13** presents measures of vehicle physical condition (and by association, vehicle quality of service, "esthetic quality," reliability, and potentially safety) as a function of vehicle age for medium- to large-size transit buses (i.e., 35 to 60 feet). This bus condition-decay curve was developed for FTA's TERM model, and the details of this process were presented at the end of the last chapter. The scale ranges from a perfect score of 5.0 (excellent) to 4.0 (good), 3.0 (adequate), 2.0 (substandard), and 1.0 (poor). In practice, most agencies retire their large buses somewhere between the conditions 2.0 to 3.0.

Within Figure 7-13, the solid center line represents the average physical condition of vehicles with roughly 35,000 in annual mileage (and average maintenance practices). The upper line represents the projected condition of vehicles with lesser mileage (25,000 miles per year), while the lower dotted line represents those with above-average mileage (45,000 miles per year). Unlike the minimum life-cycle cost analysis above, there is no obvious point at which vehicles should be retired. Rather, vehicle decay is a gradual decline in physical condition where the selection of a specific retirement point is necessarily arbitrary.

Figure 7-13



However, when the minimum life-cycle ages are plotted on Figure 7-13 (as red circles), these retirement points are located at reasonable condition values—after vehicle condition begins to decline below “adequate” (3.0), but before the vehicle attains the “substandard” designation (2.0). The lower condition value for vehicles with higher mileages (i.e., condition of the 35,000 annual mileage vehicle at minimum life-cycle cost is higher than that of the 45,000 annual mileage vehicle) is a reflection of the higher LTD mileages attained by these vehicles at the minimum cost points (i.e., 425,000 miles for vehicles traveling 25,000 miles per year; 490,000 miles for vehicles traveling 35,000 miles per year; and 540,000 miles for vehicles traveling 45,000 miles per year).

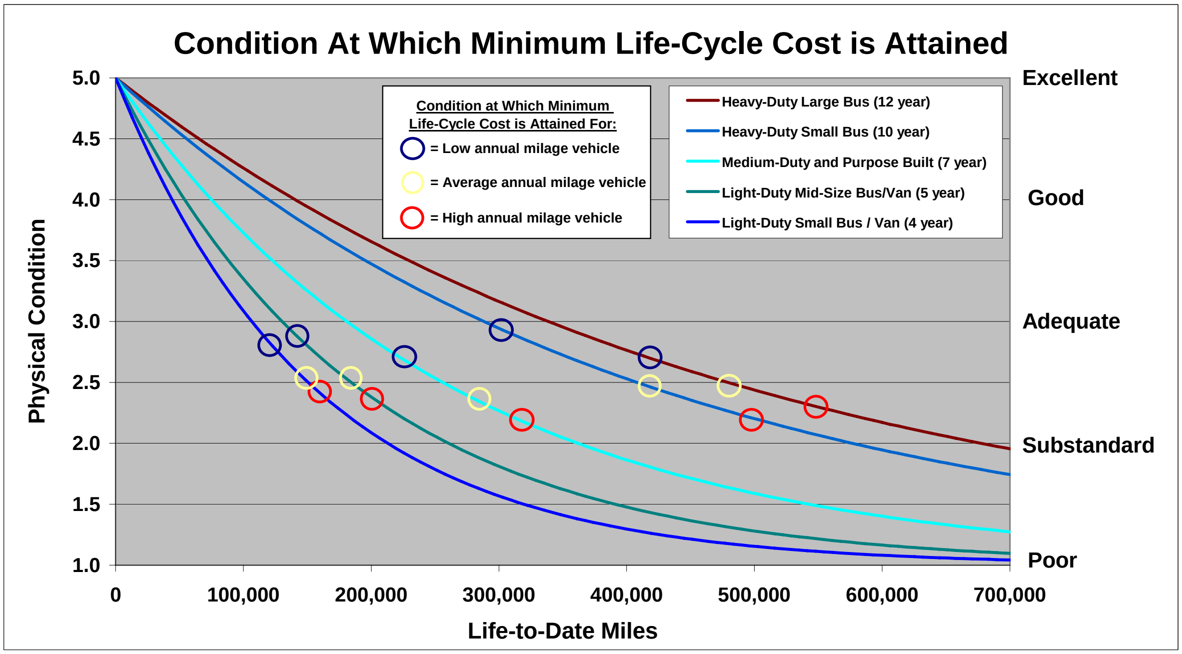
For the viewpoint of reconsidering vehicle useful life and FTA’s minimum life requirements, this cross-referencing of the minimum life-cycle cost and condition model approaches suggest that the minimum life-cycle cost ages (and mileages) represent reasonable *optimal* retirement ages (both in terms of cost-effectiveness and retirement occurring at a reasonable condition value). More importantly, these optimal retirement ages (and some mileages) occur *after* the current FTA-required retirement minimums of 12 years or 500,000 miles is satisfied. Conversely, the current FTA retirement minimums provide some margin for the early retirement of lower-reliability vehicles.

All Bus and Van Categories

Figure 7-14 identifies the condition values at which all bus and van vehicle categories attain their minimum life-cycle cost, based on total LTD mileage (and not age). As with Figure 7-13, this chart also indicates the differing condition values at the minimum cost point *within a given vehicle type* (e.g., heavy-duty, small bus). Specifically, the blue circles indicate the mileage and condition at which minimum life-cycle cost is attained for vehicles with low average annual mileage for that specific vehicle type. The yellow and red circles capture the same mileages and conditions for vehicles with average and high annual mileages, respectively.

As in Figure 7-13, the minimum life-cycle cost points for the three average annual mileage scenarios all occur at condition values less than adequate but typically well above substandard. Hence, all these retirement points are “logical” in that they occur after the vehicle’s condition has begun to show signs of age but before the vehicle begins to experience significant quality of service, reliability, or potential safety issues (as is expected for vehicles with condition ratings less than 2.0 or “substandard”). Again, it is important to emphasize that the points represented here are founded on the objective of minimizing total life-cycle cost. In practice, different transit operators or the federal and state governments may wish to target useful-life standards based on other objective criteria (e.g., a minimum quality of service).

Figure 7-14



Vehicle Age, Service Reliability, and Ridership

While transit riders are known to have a clearly stated preference for newer, cleaner transit vehicles, the study team was unable to identify any empirically based studies providing a quantitative relationship between vehicle age (or condition) and vehicle ridership. This despite the very extensive literature on the responsiveness of travel demand to many different factors (including elasticities for service price, service frequency, and travel time, and cross elasticities for gas and differences in travel time). Hence, while the qualitative response to newer vehicles is well documented (i.e., riders prefer newer vehicles and state that they are more apt to use transit given a newer, cleaner fleet), the quantitative ridership response to changes in fleet age or condition are not well documented. Given the lack of information on this subject, the study has focused on the direct ridership impacts of decreasing vehicle reliability with vehicle age as a means of addressing the issue of the ridership response to changes in vehicle condition.

Road Calls

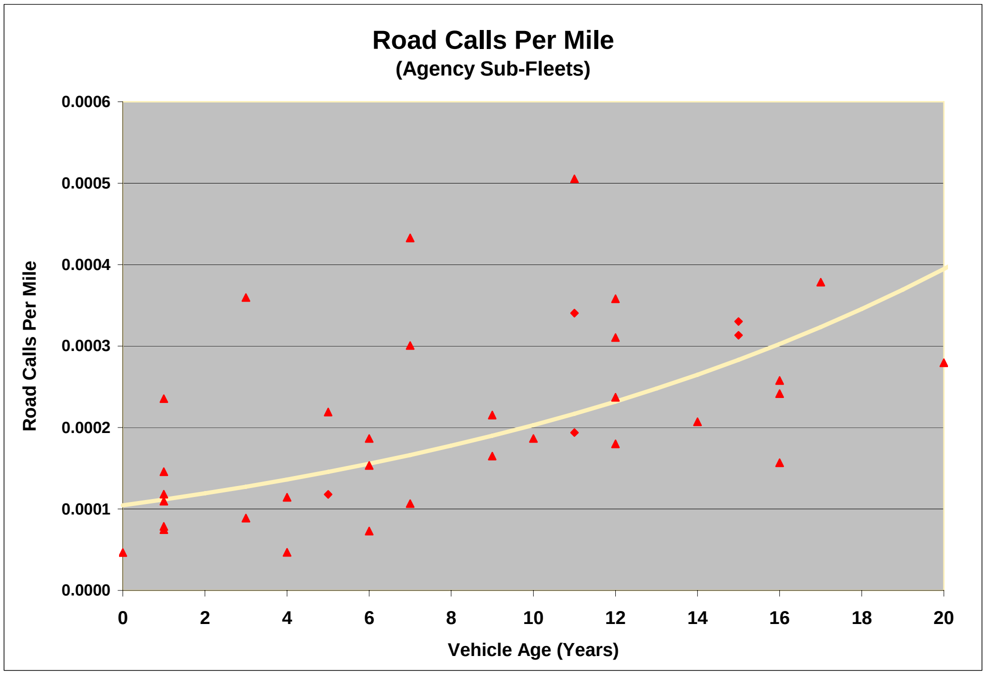
As bus vehicles age, the probability of mechanical failures increases, leading ultimately to increased service disruptions for system riders. **Figure 7-15** demonstrates the relationship between vehicle age and the number of road calls per vehicle mile (the inverse of mean distance between failures) for full-size transit buses. This relationship was developed using actual road call data from a sample of five U.S. transit operators.[11] Each point on this chart represents the average failure rate (over a 12-month period) for all vehicles in a given sub-fleet for one of these operators. For this analysis, a road call was defined as an in-service failure causing a vehicle to

---

[11]. *At the request of these operators, their names have been excluded from this presentation.*

be pulled from service (and hence resulting in a service disruption for system riders). The estimated relationship clearly captures the increasing likelihood of in-service failures as bus vehicle age increases. The surrounding data points similarly capture the wide variability in vehicle reliability resulting from both differences in the inherent reliability of different vehicle models, differences in service environment, and differences in vehicle maintenance practices.

Figure 7-15



As with the presentation of declining condition above, this analysis does not suggest a specific point in the asset life cycle at which bus vehicles should be retired (note also that the repair costs associated with these in-service failures are already captured in the minimum life-cycle cost analysis above). However, this analysis does emphasize the negative service reliability implications of increasing fleet age.

Vehicle Age, Reliability, and Ridership

As transit buses age, their appearance and ride quality typically decline, with potential negative impacts for system ridership (i.e., some riders may select an alternative to buses if bus vehicle condition falls below some acceptable threshold). Unfortunately, no prior research has been identified that assesses the impact of fleet age on system ridership.[12] However, from the relationship presented in Figure 7-15, it is clear that increasing vehicle age does lead to an increased frequency of road calls and consequently to service disruptions for the sub-group of riders impacted by those road calls. **Figure 7-16** uses the vehicle age and road calls relationship presented in Figure 7-15 to estimate the annual number of riders directly impacted by bus service failures for agencies with fleets of various sizes (i.e., 100; 500; and 1,000 buses). These

---

[12] *The study team conducted a statistical analysis specifically for this project comparing average vehicle loadings with average fleet age using NTD data to determine whether increasing average fleet has any impact on system ridership. This analysis did not identify a statistically significant relationship between these two measures.*

calculations assume an average annual vehicle mileage for these fleets of 35,000 miles per bus. They also assume an average bus passenger load of 6.8 riders (hence, on average, 6.8 riders are directly impacted by each road call or service disruption event).[13] This chart shows that increasing fleet age clearly has a significant impact on the number of riders experiencing a road call event, especially for the nation's larger operators.

Figure 7-16 presents the total number of riders impacted by road calls for differing average fleet ages. However, we must also address the incremental impact of a one-year increase in average fleet age. **Table 7-9** presents this incremental ridership impact for a range of fleet sizes and annual vehicle mileages per vehicle. As expected, the incremental numbers of riders impacted by road calls from increasing fleet age is highest for the larger transit operators and those with the highest annual mileage per vehicle.

Figure 7-16

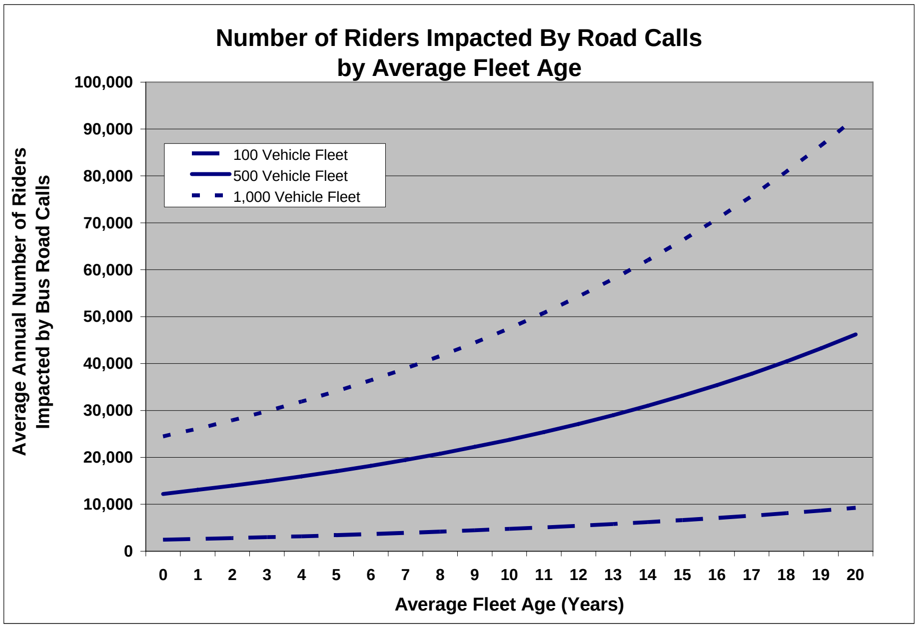


Table 7-9
Incremental Increase in Annual Number of Riders Impacted By Road Calls from One-Year Increase in Average Fleet Age

Annual Vehicle Mileage / Fleet Size	100 Vehicles	500 Vehicles	1,000 Vehicles
25,000 miles	225	1,120	2,245
35,000 miles	320	1,610	3,220
45,000 miles	565	2,823	5,645

The final consideration here is the ridership impact of declining service reliability with increasing fleet age. If it is assumed that road call and/or service disruption events motivate riders to abandon buses in favor of an alternative mode perceived to be more reliable (e.g., auto), then the numbers in Table 7-9 estimate the maximum potential ridership loss from an increase in

---

[13] *The average passenger load of 6.8 persons represents the average for all U.S. bus fleets reporting to NTD.*

service failures due to a one-year increase in average fleet age. However, in most transit markets, a significant proportion of bus riders have no viable alternative to bus, and hence are unlikely to discontinue bus use after having experienced a road-call event. Hence, it can be assumed that the actual loss in ridership resulting from increasing in-service failures with increasing fleet age is much smaller than that presented in the table above.

From the viewpoint of FTA’s minimum service life policy, the implications are as follows. First, it has been noted repeatedly throughout this report that very few agencies’ retirement decisions are constrained by the current FTA minimums (retirements that generally occur two or more years after the retirement minimums have been satisfied, and the timing of which has been determined by funding constraints). Given this situation, it is unlikely that a *decrease* in the FTA retirement minimums would impact service reliability, service quality, riders’ transit experiences, or actual ridership levels. In contrast, an *increase* in the FTA retirement minimums would begin to constrain the vehicle retirement decisions of some transit operators by forcing them to maintain their transit vehicles for a longer period of time (see Figure 4-1). In this case, the increase to the minimum retirement ages would negatively impact service quality, service reliability, rider’s transit experiences and, potentially, actual ridership levels.

CHAPTER 8. PRIOR BUS USEFUL-LIFE REVIEWS

This section reviews the results of prior useful-life research conducted by FTA and the Transit Cooperative Research Program (TCRP).

Initial Policy Statement – FTA Circular 9030.1

On June 17, 1985, FTA (at that time UMTA) issued a change to its FTA Circular 9030.1 that incorporated the service-life policy for transit buses. This marked the official public announcement of the FTA's position on the issue, which required transit authorities to operate heavy-duty transit buses for a minimum of 12 years or 500,000 miles with a maximum fleet-wide spare ratio of 20 percent. FTA officials interviewed during the development of this study stated that the 12-year service-life requirement was not based on any detailed study. Rather, it was selected based on industry's operating experience or "rules of thumb" in maintaining heavy-duty transit buses.

1985 Inspector General Statement

The 12-year requirement announced in the FTA's circular was not without controversy. Later that same year, the Inspector General (IG) unsuccessfully challenged the minimum service life policy, attempting to increase the service life from 12 to 15 years and increase the spare ratio from 20 to 30 percent.

1988 Useful Life of Transit Vehicles Study

In 1988, the FTA sponsored a study entitled "Useful Life of Transit Vehicles" (UMTA-IT-06-0322-88-1). This study focused primarily on the mechanical or engineering life of transit buses. It excluded other factors such as the economic life, ridership impacts, and technological obsolescence of the vehicle. The engineering analysis was focused on the life expectancy of the vehicle and components, and not on any measure of vehicle condition.

The key findings of this study were that the availability of capital funds and the FTA 12-year minimum were the main drivers of bus replacement decisions, that the average age of retirements was over 16 years, and that spare ratios of 20 percent were achievable with good maintenance. Recommendations included increasing the minimum requirements to at least 14 years (600,000 miles for commuter buses), allowing justified exceptions to the policy, and developing a funding policy that encourages the extension of buses beyond their minimum life requirements.

The earlier finding that the availability of capital funds is a key driver of fleet retirement decisions is consistent with the findings presented in this report. In contrast, while the 1987 study identified the 12-year minimums as a primary driver of replacement decisions for heavy-duty vehicles, agencies participating in this study rarely referred to the minimums as a decision driver. Rather, for the current study, agency participants suggested that replacement decisions were driven more by funding availability, maintenance requirements, and quality of service issues.

1988 Transit Capital Investment to Reduce Operating Deficits – Alternative Bus Replacement Strategies Study

In 1988, a study entitled "Transit Capital Investments to Reduce Operating Deficits – Alternative Bus Replacement Strategies" (National Cooperative Transit Research and Development Program (NCTRP) Report No. 15) surveyed several transit agencies to identify the major factors in current and planned bus replacement decisions. The survey found that the availability of federal funds and vehicle age are among the top considerations, while operating and maintenance cost reductions are typically not considered a driver for vehicle replacement. At that time, the average planned replacement age for heavy-duty buses for agencies participating in this study was 16. Funding constraints were a major factor in the plans to maintain vehicles in service for this length of time.

The 1988 NCTRP Report also looked at the relationship between vehicle age and various components of operating and maintenance costs, such as fuel and lubrication, engine repairs, A/C, and brakes. A key objective of this study was to develop a methodology to incorporate operating costs in vehicle replacement decisions. This is based on the study's hypothesis that the timing and extent of maintenance work affects the retirement age of a vehicle, and the retirement decision affects the need for major work. The actual study analysis was limited by data availability, although the researchers did find a strong correlation between vehicle age and vehicle maintenance and rehabilitation costs. The methodology developed by this study was designed to guide transit managers in evaluating the trade-offs between continuing to operate an existing vehicle "as is," replacing it, or significantly rehabilitating it.

1995 Bus Industry Summit

On September 22, 1995, FTA convened a Bus Industry Summit to identify and discuss industry concerns related to FTA's bus service-life policy. The summit yielded a broad diversity of opinions on vehicle useful life and several suggestions on how FTA might consider altering its service-life requirements. For example, many summit participants suggested that FTA's 12-year service-life standard for 40-foot buses should be reexamined. These discussions included suggestions to both lengthen and shorten the minimum service-life requirement:

- *8-Year Bus:* Some manufacturers suggested moving to an 8-year service-life minimum. It was suggested that this would ensure that the latest technological advances could be introduced sooner, leading to cleaner, lighter, safer, and more fuel-efficient buses. It would also expand the size of the overall market, potentially increasing the viability of the domestic transit bus market.
- *General Reduction in Service Life:* Some agency representatives concurred with the general objective of a reduced service-life requirement under the expectation that this would enhance the vehicle, thus driving down the base vehicle process and accelerating the adoption of new technologies. The anticipated results were improved service quality and a stabilized vehicle market.

- *15-Year Bus:* FTA staff noted that the U.S. DOT Inspector General considered a 15-year service-life standard because of the lessened need for federal capital funds.
- *18-Year Bus:* A bus builder noted that Ontario, Canada, has an 18-year standard with a substantial overhaul scheduled for year 12. The practice of extending vehicle useful life to 18 years or more through enhanced initial design and materials specifications, improved maintenance practices, and application of more extensive and frequent vehicle rebuild programs has spread throughout Canada due to the lack of national capital funding for bus replacement.
- *Flexible Policy:* Some participants argued that national policy should be flexible and should not be based on a "one size fits all" service-life standard. They argued that a single standard cannot consider differences in:
    - Climatic and demographic circumstances
    - Budgetary constraints and priorities of transit operators
    - Overall operating expenses
    - Maintenance practices and maintenance management systems
    - The types of operating systems on buses
    - Rebuilding and replacement policies.

These varied responses show that there was no clear consensus among the Bus Industry Summit participants on an optimal minimum service-life policy. Also, in addition to these suggested changes in overall vehicle useful life, it was also pointed out that useful-life issues directly impact decisions concerning the approach to warranty programs. Maintenance management systems and rebuilding schedules are also impacted.

Overall, the meeting highlighted the need for analysis that would consider all of the factors that bear on the relative costs and benefits of moving to an alternative service-life standard. For example, maintenance and fuel costs; the impact on service quality for riders; early deployment of new safety, efficiency, and technical features; the health of the bus manufacturing industry; and funding impacts on a longer-term basis must be examined when considering changes in current replacement parameters based on a specified useful life.

1997 Useful Life of Heavy-Duty Transit Buses Study

In 1997, the FTA sponsored a second study entitled, “Useful Life of Heavy-Duty Transit Buses” (TCRP Project J-6, Task 15). This study was commissioned based on feedback from industry received during the FTA-sponsored Bus Industry Summit meeting (see above). This study expanded on the 1988 study by addressing variables such as operating environment, regulations, technology, maintenance practices, and operating economics.

The purpose of this special study was to review relevant data in order to make recommendations on the appropriateness of the current service-life standard for heavy-duty transit buses. The effort included an analysis of factors that impact vehicle life, including the operating environment (e.g., climate; terrain; annual bus mileage; average operating speed; and urban, suburban, or rural);

requirements mandated by the ADA, Clean Air Act Amendments, and others; and the introduction of new technologies (e.g., alternative fuels, advanced electronics).

This study identified duty cycle as likely the most important variable affecting vehicle life, with the life of buses decreasing as the severity of the duty cycle increases. The study suggested that average operating speed could be used as a proxy for duty cycle severity in future useful-life analyses.[14] Recommendations included changes to the current service-life policy to consider the total age of the fleet (and not the age of the individual vehicles) and the type of service the vehicle is operated under. FTA's age and mileage standards were not changed following this study.

Other Studies

The following are descriptions of several additional studies that have addressed the issue of transit vehicle useful life:

- In 1995, the New York Metropolitan Transportation Authority Office of the Inspector General published a report evaluating the then-perceived deterioration in the condition of New York City Transit's bus fleet. At that time, one-third of the fleet was over the 12-year minimum retirement age and older buses were experiencing significant corrosion and parts failures. The report attributed the poor conditions to the failure of management to establish and enforce preventive maintenance procedures, and poor capital planning to purchase new vehicles and operate and maintain older age vehicles. Recommendations emphasized the need for adequate maintenance and inspection policies, especially targeted to buses over 12 years of age.
- In 2004, a group of university researchers led by Li et al developed a model to explore the contribution of preventive maintenance to vehicle condition. Vehicle condition ratings (or the probability of a vehicle being at a condition rating) were calculated based on the vehicle's age, mileage, and amount of maintenance spending. The decision analysis model evaluated the benefit/cost ratio of the expected gain from extended life that would result from specific maintenance/repair actions and the associated costs. The model developed in this study introduced a quantitative measurement of the expected benefits of maintenance actions on the vehicle life cycle. The analysis clearly indicated a relationship between vehicle condition, useful life, and preventive maintenance practices.
- The 1988 Pennsylvania Department of Transportation (PennDOT) "Handbook" is a guide to assist transit agencies purchasing small transit vehicles. The handbook contains information on the characteristics of small transit vehicles, PennDOT procurement procedures, and optional equipment with technical specifications and costs. The expected life reported for standard vans, body on chassis vehicles, and small buses is 3 to 5 years, 5 to 7 years, and 10 to 15 years, respectively, all depending on a number of factors, such as operating environment and preventive maintenance programs.

---

[14] *Note that the analysis in Chapter 7 uses average agency operating speed as a cost driver for O&M costs. However, this study was unable to demonstrate quantitatively a relationship between decreasing operating speed and decreasing vehicle life expectancy.*

- The Small Transit Vehicle economics (STVe) model was developed by a group of university researchers and is designed to support decision-makers purchasing small transit vehicles. The model provides an economic evaluation of various types of vehicles given the inputs of operating conditions such as type of service and capacity. Types of vehicles, listed in Table 8-1, are categorized based on characteristics that affect capital, maintenance, and operating costs. The vehicle categories presented in the table and the expected useful lives for each of these categories are all roughly similar to those currently used by FTA.

Table 8-1
Small Transit Vehicle Economics Model

Category	Description	Approx. Seating Capacity	Expected Life⁺
1	Van	10 – 11	4
2	Van Cutaway, Single Wheel	13	4
3G	Van Cutaway, Dual Wheel, Gasoline	18	5
3D	Van Cutaway, Dual Wheel, Diesel	18	5
4	Purpose Built, Front Engine	22	6
5	Purpose Built, Rear Engine	22	7
6	Medium-Duty, Low-Floor Front Engine	20	7
7	Heavy-Duty, Low-Floor, Front Engine	Varies	12
8	30 ft., Heavy-Duty Bus	Varies	12
⁺ As considered in the STVe model			

Comparisons of Past Studies with This Report

Largely, the findings of the studies sited above appear to be consistent with the findings reported elsewhere in this report. Key common findings between this and prior studies include:

- Transit buses (heavy-duty buses in particular) generally have many years of valuable service life well after the service minimum age has been reached. Also, operators generally retire their vehicles well past this point in time.
- Vehicle retirement decisions are driven less by the service-life minimums than they are by funding availability, maintenance requirements, and quality of service issues.
- Economic and engineering analyses suggest that the current FTA service-life minimums are generally appropriate for each of FTA's five minimum service-life categories (i.e., there is no clear need to change the categories or the service-life minimums for each category).
- Duty cycles (as measured by the average operating speed proxy) are a key driver of vehicle useful life, especially for vehicles operated in fixed-route service.
- There are diverse opinions among industry representatives as to the preferred useful life of heavy-duty (i.e., 12-year) transit vehicles, ranging from 8 to 15 years or more.
- There is value in having some flexibility in the application of the service-life minimums to reflect differences in agency service environments and to address the issue of problem vehicles.

Other Considerations

In addition to the considerations outlined above, review of FTA’s minimum service-life policy for transit buses and vans can also gain perspective from a brief review of this subject from different perspectives. To that end, the following sub-sections consider bus useful life from the viewpoints of the New Starts cost-effectiveness evaluation and the experience of Canadian transit agencies operating essentially the same transit buses as their American counterparts, but for several additional years of useful life.

New Starts Program Impacts

For FTA’s New Starts program, asset useful life values, including those for transit vehicles, are used to determine the total annualized cost of proposed New Starts investments. New Starts projects with low annualized capital costs tend to have more favorable cost effectiveness and net benefit measures relative to those with higher annualized capital costs. Hence, revisions to FTA minimum service-life standards (the standards also used to annualized vehicle costs for New Starts investments) can have the potentially unexpected impact of lowering or increasing the cost-effectiveness measures for New Starts investments with bus or van components (e.g., BRT investments). Longer useful life results in increased years that vehicle capital costs will be spread over within the annualized cost calculation, thus reducing the project’s cost-effectiveness measure (increasing net benefits).

Note that this issue has already arisen with respect to some BRT designs intended to have a useful life of approximately 18 years. Assigning an 18-year minimum useful life value to these vehicles (versus the current 12-year value for large buses) would make these vehicles more competitive with similar rail investments.

The Canadian Experience

As already noted, Canadian transit authorities do not receive bus replacement funding assistance from their national or provincial governments. Because of this, Canadian transit agencies tend to operate their buses longer and maintain a larger spare fleet than their U.S. counterparts. It is not clear how the service life of Canadian buses is influenced by the lack of Canadian federal assistance versus the fact that these operators have no spare ratio maximum. Either way, Canadian transit agencies have been operating transit buses with similar designs to U.S. buses for 15 years on a consistent basis and have extended them to the 18-year range through enhanced designs and more extensive component replacement programs.

Canadian agencies have also conducted cooperative research efforts into bus designs and the available means to extend useful life through more aggressive design specifications. The results of these approaches are evident in the extended useful bus life for these operators’ vehicle fleets. However, the extent to which this longer vehicle life is driven by differences in bus design is not fully clear given that these agencies have higher spare ratios, providing them with a larger pool of buses to draw from when problems are encountered within an aging fleet. The conclusion then is that vehicle life can be prolonged significantly from the current FTA minimums for large buses. The uncertainty is the full costs and service quality implications of extending vehicle life beyond 15 to 16 years.

Case Study – U.S. versus Canadian Useful Life

The transit bus industries in Canada and the United States use virtually identical vehicles, and the services provided are very similar. In both countries, the majority of agencies are municipal. Interestingly, three of the six largest North American transit bus manufacturers are Canadian, or have significant Canadian-based manufacturing facilities.

Table 8-2
Geographic Locations of Major North American Bus Manufacturers

Manufacturer	Head Office	Canadian Facilities	American Facilities
New Flyer	Winnipeg, MB	Winnipeg, MB	St. Cloud, MN Crookston, MN
Nova Bus	St-Eustache, PQ	St-Francois-du-lac, PQ	N/A
Orion Bus	Mississauga, ON	Mississauga, ON	Oriskany, NY
NABI	Anniston, AL	N/A	Anniston, AL
Gillig	Hayward, CA	N/A	Hayward, CA
Millennium	Roswell, NM	N/A	Roswell, NM

While there is significant Canadian content in the manufacturing and assembly of the buses, the majority of the major components going into the final product, specifically the high-dollar/high-value items such as engines, transmissions, axles, and HVAC are all supplied by non-Canadian companies, and are almost exclusively U.S. companies. In addition, exporting to the United States is critical for both New Flyer and Orion, who have large U.S. facilities in order to meet the Buy American requirements.

Despite the similarities in the vehicles manufactured in the United States and Canada, there is a significant difference in agency requirements for useful life. As just noted, Canadian agencies expect an 18-year useful life versus 12 years in the United States—a 50-percent increase above the U.S. requirement. Other distinguishing characteristics between the U.S. and Canadian markets are reflected in the higher usage and productivity of urban transit in Canada. Canadian transit use per capita is 150 percent of the U.S. use (1.44 billion trips versus 9.17 billion trips). Of these trips, it is estimated that 75 percent are made by bus in Canada compared to just over 60 percent in the United States. Government funding (from all levels combined) on a per-capita basis is less than 80 percent of the U.S. level.

The buses used in the United States and Canada are virtually identical in design and purchased using similar specifications and procurement approaches. Regardless, Canadian agencies expect the vehicle to have an 18-year life. From our interviews with agencies and manufacturers, there are two leading factors driving this difference in expected bus life:

1. Federal capital funding for transit is non-existent in Canada. Other than intercity rail, all transit funding in Canada is a provincial responsibility.

2. Provinces have not established long-term funding allocations. While annual operating budgets are supplemented, there is not an established formula for capital vehicle replacements similar to the FTA.

The U.S. agencies interviewed have adapted to the FTA's 12-year useful life for transit buses primarily because it is tied to the FTA's 80-percent funding. Agencies have adjusted their internal funding and planned vehicle replacement schedules to match the established FTA funding streams. In Canada, where there is no established funding formula for vehicle purchases, agencies must plan to keep their vehicles longer. Agencies have therefore focused on an 18-year vehicle life.

CHAPTER 9. KEY FINDINGS AND RECOMMENDATIONS

Key Findings

Following are key findings from this study.

Review of FTA's Current Service-life categories

The review of FTA's minimum service-life requirements yielded the following key findings:

- **The current service-life category groupings are appropriate.** The study found that the current categories represent logical groupings of vehicles having broadly similar characteristics in terms of construction methods, size, weight, passenger capacities, cost, manufacturers, and customer bases. A possible exception here is for 4-year and 5-year vehicles built using cutaway chassis where there is a significant degree of overlap between the two age categories in terms of construction type, sizes, and manufacturers.
- **Transit has little ability to alter bus and van useful-life characteristics cost-effectively.** Given transit's small share of the vehicle and component markets (typically less than one percent), the transit industry has little ability to influence component useful-life characteristics in a cost-effective manner. A key exception here is the structure of 12-year buses. To the extent that 12-year bus structures are designed specifically for transit use, the transit industry has some leverage to influence this component's design and durability characteristics.

Review of Procurement Regulations with Potential Useful-Life Implications

While many federal regulations (e.g., Buy America, Bus Testing, ADA, and EPA) and industry procurement practices (third-party contracting) are believed to have potential useful-life implications, these implications are generally considered minor relative to the issues of annual mileage, new vehicle designs, changing life-cycle economics, and other drivers of useful life.

Analysis of Actual Retirement Ages Using NTD Vehicle Data

The study used NTD data to determine how recent *actual* retirement ages for transit buses and vans compare with FTA's current minimum service requirements for transit buses and vans to determine whether these requirements are affecting the vehicle retirement decisions of the nation's transit operators.

- **Most buses and vans retired well after the minimum service age requirement is satisfied.** On average, transit buses and vans are retired between one to three years after their minimum service-life requirement has been satisfied (Table 9-1). In addition, a significant proportion of buses and vans remain in service at least one year past the retirement minimum (e.g., 20 percent of heavy-duty, 12-year buses), and with many still in service three or more years past the minimum requirement (e.g., one in ten "12-year" buses in active service are age 15 or older).

Table 9-1
Minimum Versus Average Retirement Age by Vehicle Category

Vehicle Category / Minimum Retirement Age	Average Retirement Age (Years)	Share of Active Vehicles that are:	
		One or more years past the retirement minimum	Three or more years past the retirement minimum
12-Year Bus	15.1	19%	9%
10-Year Bus*	?	7%	4%
7-Year Bus	8.2	12%	3%
5-Year Bus / Van*	5.9	23%	5%
4-Year Van	5.6	29%	10%

* Average retirement age estimates for these vehicle categories suffer from small sample issues

- **Minimum service age does not constrain agency vehicle retirement decisions.** Relatively few transit buses and vans are retired right at the minimum service age requirement. Hence, the current retirement minimums are not constraining the vehicle retirement decisions of the vast majority of the nation's bus and van operators. This indicates that any reduction to the current minimum age requirements (e.g., from 12 to 10 years for a "12-year bus") would not result in a significant increase in the rates of retirement for the five service-life categories.

Industry Outreach

Representatives of local transit operators, vehicle manufacturers, and private bus fleet operators were interviewed to assess their current experiences with bus and van useful life. The following are key findings from this industry outreach process:

- **Actual retirement ages generally exceed both FTA minimums and agency service-life policies.** The actual timing of vehicle retirement for all nine agencies typically occurs between one to four years after the FTA minimum has been reached (but can occur as late as vehicle age 20). Moreover, for most agencies the recent actual retirement ages also exceed the planned or policy retirement age. Hence, it is clear that FTA's current minimum service-life requirement is not actively constraining these agencies' retirement decisions.
- **Capital funding availability is the primary determinant of retirement age.** Limited capital funding was cited as the primary reason why the timing of actual vehicle retirements has exceeded the planned and policy retirement age (and FTA service minimums). Because of this, the average fleet age is more likely to be impacted by the increased availability of federal funding than by any relaxation in the minimum service-life requirements. Other decision factors included service reliability, vehicle condition, vehicle maintenance, physical and local environmental conditions, procurement process, and duty cycle (operating speed, mainly).
- **Only large agencies operating in severe environments perform scheduled mid-life overhauls.** Only the larger, urbanized agencies interviewed (Massachusetts Bay Transportation Authority, New York City Transit, Toronto Transit Commission, and Washington Metropolitan Area Transit Authority) perform comprehensive, "mid-life"

overhauls of their heavy-duty cycle vehicles, stating that these overhauls are required to obtain full service lives given the tough service environments in which they operate. In contrast, none of the other agencies interviewed (including Los Angeles Metropolitan Transportation Authority and Houston Metro) regularly complete a mid-life overhaul, with most suggesting it is not cost effective for them.

- **Most agencies reported not being impacted by FTA's service-life requirements.** Most interviewed agencies stated that their vehicle retirement decisions are not significantly impacted by FTA's service-life minimums (these decisions are constrained more by capital funding availability).
- **Extending the service-life requirements would hurt many agencies.** Conversely, most, if not all, of the agencies reported that they would be negatively impacted if current FTA minimum service lives were extended. These negative impacts include a decrease in quality of service (higher rate of failures, aesthetic of vehicles, reliability), an increase in maintenance costs (between 10 to 50 percent higher), and less leeway to retire "problem" vehicles.
- **Agencies support development of a "lemon law" and a technology demonstration option.** Interview respondents supported development of a "lemon law" and a technology demonstration option. The lemon law concept would permit early retirement of problem vehicles without penalty to the agency. Under the technology demonstration concept, a grantee could request a similar release from the service-life policy for FTA-approved tests of new vehicle technologies.
- **Most agencies were not interested in more or less durable heavy-duty vehicles.** Most agencies stated that they were not interested in a more durable vehicle (i.e., with a more expensive, heavier weight, longer life expectancy structure). This is due to concerns over the cost effectiveness, weight, and rider comfort for this option. All nine agencies also expressed significant concerns with a less durable vehicle (i.e., with a cheaper, lighter weight, lower life expectancy structure). There were concerns regarding the expected inability to survive the required duty cycles and the relationship with a decrease in quality and an increase in procurement efforts.

Engineering Analysis

The engineering analysis provides further evaluation of bus useful life from a vehicle engineering perspective. The following are key findings:

- **Useful life is ultimately determined by the life of the vehicle structure.** Vehicle structure defines the useful life of the vehicle as a whole more than any other single vehicle component. Should the structure wear out or fail due to corrosion or a collision, then the life of the vehicle is essentially at an end.
- **Service environment is a key determinant of structure useful life.** Many interview participants clearly indicated that service environment is a key determinate of structure (and hence vehicle) useful life. Because of this, several agencies expressed the desire that FTA revise the service-life requirements definition to include service environment severity, along with service years and miles (e.g., 12 years or 500,000 miles).

- **"Stick bus" and low-floor vehicles may have shorter useful life.** Interview participants suggested that stick bus (structures constructed using hundreds of welded tubes) and low-floor designs (which use stick construction) may have shorter useful life as compared to traditional designs. Interview participants stated that it is too early to tell whether this is in fact the case.

Economic Analysis

The economic analysis identified the age for all vehicle categories at which total life-cycle costs—including all capital, operating, and maintenance costs—are minimized (reflecting the impact of differences in mileage). This analysis identifies a financially optimal retirement point for the vehicle.

- **The minimum cost retirement points all occur at or after the FTA minimum service life.** From a cost-effective perspective, FTA's current service-life minimums—including both the minimum years and miles requirements—represent reasonable choices. For each service-life category, the minimum cost point is attained at either an age or mileage that exceeds one or both of the FTA minimums for these measures.
- **Reducing heavy-duty vehicle service life from 12 to 10 years would only have a minimal impact on vehicle sales.** Assuming all vehicles currently retired right at the current 12-year minimum shifted to a new 10-year minimum, the long-term average annual replacement rates for these operators would increase from 200 to 300 vehicles to 240 to 360 vehicles annually, or 40 to 60 additional vehicles per year. The addition of 40 to 60 additional new vehicles is unlikely to yield a significant boost to the small domestic bus market.

Recommendations

Based on the findings above, it is recommended that the FTA consider the following:

- **Maintain the current service-life minimums:** Few buses and vans are currently retired right at FTA's current service-life minimums. Rather, the vast majority of these vehicles are retained in service for at least one year (4- and 5- years vehicles) and as many as three or more years (e.g., for 12-year vehicles) after the minimum service requirements have been met, indicating that these vehicles have some service life remaining beyond the minimums. Moreover, the current service-life age and/or mileage minimums for all vehicle types occur *before* the minimum life-cycle cost points for these vehicles are reached. Hence, the current service-life minimums clearly meet the joint objectives of (1) ensuring that buses and vans purchased using federal dollars remain in service for most of their useful life, (2) of providing agencies some flexibility in determining when their vehicles will be retired and (3) of helping to minimize life-cycle costs. In this sense, the current service-life minimums really are just that, the *minimum* ages at which vehicles can be retired—not a recommended retirement age or a measure of actual expected useful life. The current minimum service-life requirements should be maintained.
- **Maintain the current service-life categories.** Similarly, the segmentation of transit bus and van types into the current five service-life categories reflects actual similarities in vehicle

structures, designs, components, costs, origin markets, manufacturers, and end users. These current categories should be maintained.

- **Review the service-life minimums and service-life categories regularly.** The analysis of recent changes in vehicle designs, the adoption of new technologies, and the introduction of new vehicle types (e.g., stainless steel BRT vehicles) highlight the fact that the useful-life characteristics of transit buses and vans are subject to change. For this reason, FTA should review the minimum life requirements and service-life categories on a regular basis (e.g., every 5 to at most every 10 years).
- **Consider adoption of a "lemon law."** This law would define circumstances under which "problem" vehicles could be retired early without financial penalty.
- **Consider adoption of a technology demonstration option.** Similar to the "lemon law," this option would define circumstances under which agencies could retire vehicles purchased to test new technologies (with FTA's prior agreement) early, again without financial penalty. The intention would be to encourage test and adoption of new, but potentially unreliable, technologies expected to benefit the entire transit industry.
- **Restrict the service-life categories in which vehicles are tested.** In recent years, some manufacturers have successfully lobbied to have their vehicles tested in a more durable category than would appear warranted by their vehicle's general characteristics (e.g., testing a bus with 10-year characteristics as a "12-year" bus). The result has been service reliability issues and, in some instances, early retirement for the purchasing agencies when the tested vehicles were not found to have the expected durability. Thus, FTA may wish to more tightly control which categories vehicles are eligible to test in based on some combination of characteristics (e.g., gross vehicle weight, seating capacity), but with the potential for special waivers to test in a different category so as not to stifle innovation. (Manufacturers should be required to provide reasonable justification as to why their vehicles should be tested in the higher durability category.)
- **Modify the NTD reporting requirements to better document actual vehicle retirement age and each vehicle's assigned service-life category.** The analysis used in this study to determine actual vehicle retirement ages relied on cross comparisons of NTD data from multiple reporting years to identify when specific vehicle sub-fleets have been retired. FTA should modify NTD to track the actual age of vehicle retirements, thus significantly improving FTA's ability to track and monitor any trends in vehicle retirement ages. Similarly, NTD's vehicle documentation should also include the service-life category to which each vehicle has been assigned (again to facilitate monitoring of the retirement ages for each service-life category).
- **Conduct a study to evaluate the sensitivity of bus ridership to changes in vehicle age and condition.** A key objective of this study was to consider how bus ridership might change (increase) in response to a reduction in the average age of the nation's bus fleets (e.g., with the introduction of a new, shorter lived, heavy-duty transit vehicle). However, while review of the existing literature provides numerous references to the sensitivity of ridership to changes in fares and service frequency, no literature references were identified that provide a quantitative link between ridership and fleet age or condition. In the absence of solid empirical data linking ridership and fleet age, any analysis of this relationship can only be

based on conjecture and limited anecdotal evidence. For this reason, it is recommended that FTA conduct a study to evaluate the sensitivity of bus ridership to changes in vehicle age and condition. Given the availability of good-quality, route-level ridership data (from electronic fare boxes and APCs), this study could easily be conducted using a sample of U.S. transit operators, using before and after comparisons of which older sub-fleets have been replaced by new (or newer) vehicles.

BIBLIOGRAPHY

The following documents have been used as project resources.

1 Books, papers, technical reports:

Federal Transit Administration. 1988. “Useful Life of Transit Vehicles.” UMTA-IT-06-0322-88-1. Washington, DC: U.S. Department of Transportation.

> This study focused primarily on the mechanical or engineering life of transit buses. It excluded other factors such as the economic life, ridership impacts, and technological obsolescence of the vehicle.

Abrams, E. and E. Hide. 1997. “Useful Life of Heavy-Duty Transit Buses.” TCRP Project J-6, Task 15. Washington, DC: Transportation Research Board.

> This task reviews FTA guidelines on the minimum useful life of 12 years or 500,000 miles of operation for heavy-duty buses. The study expanded on the 1988 study and includes an analysis of factors that impact vehicle life (operating environments, mandated requirements, and new vehicle technologies) and makes recommendations on the appropriateness of the current service-life standards.

American Public Transportation Association. 1997-2002. “Standard Bus Procurement Guidelines.”

> This is a comprehensive set of industry-wide purchase standards, with both technical specifications and procurement guidelines for transit buses.

Booz Allen Hamilton. 2005. “Managing Capital Costs of Major Federally Funded Public Transportation Projects.” TCRP Project No. G-07. Washington, DC: Transportation Research Board (TRB).

> This report examines the strategies, tools, and techniques to better estimate, contain, and manage major transit capital projects. Nine case study projects were examined in detail to provide insight into various project management approaches. Major cost drivers considered in this analysis were initial inflation, scope changes, and schedule changes.

Yang, F., L. Yu, G. Song, W. Wang, and W. Pei. 2004. “Vehicle Age Distribution Model and Application for Beijing, China.” Washington, DC: Annual Meeting of the TRB.

> This paper proposes a survival probability-based model to calculate and forecast the area-specific vehicle age distributions, which uses the total number of registered vehicles (not distinguished by years) and the total number of newly registered vehicles or the number

of scrapped vehicles (the most recent year). The model is designed for areas where historical vehicle registration records are incomplete or unavailable.

Li, Q., H. Zhao, and Y. Xingping. 2004. "Decision Making Modeling for Rural and Small Urban Transit Asset Management." Washington, DC: Annual Meeting of the TRB.

This paper describes the framework of a transit asset management system and discusses the methodologies developed to assist agencies in foreseeing the transit deterioration process. The study explores the contribution of preventive maintenance costs to the vehicle condition ratings. The optimization procedures developed help allocate sufficient funding to sustain future well-being of transit vehicles. The concept of extended life (payoff for maintenance actions) of transit vehicles is introduced to provide a structure for the management decision-making process.

KFH Group, Inc. 2000. "Analyzing the Costs of Operating Small Transit Vehicles." TCRP Report 61. Washington, DC: Transportation Research Board.

This report serves as a user guide to the accompanying Small Transit Vehicle economics model, which is designed to provide support to transit planners and other decision-makers on the purchase of small transit vehicles for different services and operating environments. The user guide also discusses qualitative and non-financial factors that influence the size of vehicles to be purchased.

Schneck, D. C., and R. S. Laver. 1995. "Transit Capital Cost Index." Washington, DC: Annual Meeting of the TRB.

This study presents the results of research aimed at improving the estimation of future capital costs for light and heavy-rail fixed guideway projects. The research produced a set of cost indices for a broad range of project elements, comparing these cost indices with broader measures of inflation and suggesting how they should be incorporated into cash flow projections for proposed fixed guideway projects.

Pennsylvania Department of Transportation (PennDOT), Bureau of Public Transportation. 1988. "Handbook for Purchasing a Small Transit Vehicle." Urban Mass Transportation Administration. Washington, DC: U.S. Department of Transportation.

This handbook was developed to assist Pennsylvania grantees in the vehicle procurement process. The first part of the handbook contains information on the characteristics of small transit vehicles, objective criteria for selection, and PennDOT procurement procedures, while the second part provides a list of optional equipment and features with their technical specifications and approximate costs.

Metropolitan Transportation Authority. Office of the Inspector General. 1995. "Is New York City Transit's Bus Fleet Too Old to Provide Reliable and Safe Bus Service?" TRA 450.6-4 ISNYC 94-79636. New York, NY: New York State Library.

This document reviews the conditions and problems of the New York City Transit bus fleet, which at the time had one-third of its buses over the 12-year retirement criterion. Age-related safety, performance, and structural deficiencies are examined. The report offers a number of recommendations to restore the fleet to a state of good repair and monitor the condition of its overage vehicles.

Hemily, B., and R. King. “The Use of Small Buses in Transit Service.” TCRP Synthesis Report 41. Washington, DC: Transportation Research Board.

This research explores the use of small buses (30 feet or less) in the transit industry. The study included a survey of North American transit agencies using small buses, transit agencies that do not have small buses, and bus manufacturers. Results from this research were related to the fleet composition with respect to small buses, the wide variety of vehicle models and service categories, and overall experiences and most common areas of concern for transit agencies regarding small buses.

2 FTA and agency reports:

Federal Transit Administration. 2006. “Non-Rail Vehicle Market Viability Study.” MI-26-7008-05.1. Washington, DC: U.S. Department of Transportation

Federal Transit Administration. 1988. “Useful Life of Transit Vehicles.” UMTA-IT-06-0322-88-1. Washington, DC: U.S. Department of Transportation

Federal Transit Administration. 1998. “Urbanized Area Formula Program.” Circular C9030.1C. Washington, DC: U.S. Department of Transportation.

Federal Transit Administration. 1995. “Final Report: Bus Industry Summit Proceedings.” Washington, DC: U.S. Department of Transportation.

Federal Transit Administration. “Buy America Requirements – Surface Transportation Assistance Act of 1982.” 49 CFR 661. Washington, DC: U.S. Department of Transportation.

Federal Transit Administration. “Bus Testing Regulation.” 49 CFR 665. Washington, DC: U.S. Department of Transportation.

Americans with Disabilities Act of 1990. United States Public Law 101-336.

3 Internet sources:

Altoona Bus Research and Testing Center. <http://www.vss.psu.edu/btrc.htm> (January 16, 2006)

American City & County. “Public Transit/Commission Uses Third Party for Bus Procurement.” <http://www.americancityandcounty.com/mag/government_commission_uses_third/index.html> (January 13, 2006)

This article describes the bus procurement process taken by the Metropolitan Transit Commission (MTC) in St. Cloud, MN.

Hubbard, D. 2005. "If It Makes It Here, It Can Make It Anywhere." BUSRide Magazine. <https://www.busride.com/2005/07/If_it_makes_it_here_it_can_make_it_anywhere_.asp> (January 16, 2006)

This article is about the Altoona Bus Research and Testing Center (ABRTC).

Goby, D. 2004. "The Environment and New Bus Service Life." School Transportation News. <http://www.stnonline.com/stn/busmaintenance/schoolbustechnician/goby_buslife0404.htm> (January 16, 2006)

This is an opinion article on the environmental impacts of school buses with six- to eight-year service life compared to longer (10 to 15 year) service life.

APPENDIX A. SUMMARY OF TRANSIT AGENCY SURVEY

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
General Experience - Federal Funding									
Use Federal funding to purchase buses and vans? (y/n)	Yes	Limited	Few (some State funded - which is partially funded with federal sources; most are from County	No, use MTA/NY State Capital Funds	Yes	Yes	Yes	Yes	Yes
Percent of fleet purchased using Federal funds	100%	Limited diesel hybrid support on a demonstration basis (150 buses) - 1/3 city, 1/3 province and 1/3 federal; Rest of fleet is funded by agency or city;	Not given	0%	100%	Not stated	25-30%. Other funding sources: State and Local	99%	95%
General Experience - Service-life policy (Heavy-Duty Vehicles)									
Have policy in place? State or agency?	Yes – imposed by WMATA board	Yes	State (more stringent than FTA) and County policies	Not stated (use average age of fleet to make sure garages have equal distribution - not for policy)	Yes (use average age of fleet)	Yes	Follow State policy, which is similar to FTA. (see table)	Yes	Yes
Planned / agency policy retirement age	15 years for 40-foot	18 years at 40-45,000 annual.	12 for County funded; none stated for State funded	12 years as an objective	12 years	13 years or 500,000 miles		(not given)	“12-year” bus, retirement target is age 15; “7-year” is age 9, 5-year bus target is age 8, and 4-year is age 5
Preferred retirement age from the viewpoint of agency staff	5 years due to funding limitations/constraints	18 year, can extend to 20-24 to correspond with procurement cycle	Same as FTA/MD	12 years	8 years	12 years (Budget)	Yes, FTA/MTA minimums; Maintaining vehicles for longer period is too expensive	Same as scheduled	Same as scheduled

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
Do actual retirement ages differ from the scheduled retirement age?	Difficulties with Thomas SLF's (scheduled at 12, failing at 10-11)	States NO, but CNG buses had to be retired at 12-years due to high maintenance	Close to minimum life; budget not a problem (delay usually due to procurement process)	Yes, 13-15 years due to lack of funding (structural rebuild and re-power program to extend)	Yes. Actual exceeds scheduled due to other funding priorities. Use average age of fleet. Target is 8 years for fleet average age, unable to meet this because of limited funding	Yes, due to budget and legal consent degree obligations	Yes, but retirement was within 1-2 years for minimums; Minibuses (retired at 6 years, 145,000 miles) were very old. Cutaways (retired 6 years, 210,000 miles) very old.	No	Yes, Prior to 4 years ago, no established replacement schedule existed.
Examples of recent sub-fleet retirements	Group of 1983 MAN artics, operated barely 11-12 years (12-year sched) and 400k-500k miles (600k sched). All other groups retired at scheduled miles or more.		Group of 1984 30-ft TMCs (retired 1999 - 15 years: Expensive to maintain. Group of 1989 30-ft Gilligs (retired 2001/2002 - 12 years), had been re-engined 1992/1993: no lift, poor a/c, expensive maintenance, drivers hated	Group of 1987 RTS (20-30k mi/yr, retired 2006), kept in reserve fleet while other vehicles were in overhaul. Group of 1990 RTS (retired 2006, 360-380k miles total): 1990 RTS not sent through re-power program, no engine replacement w/o failure	Retired 03/2006 heavy duty: Schedule 8, Actual 16. Retired 12/05 heavy duty: Scheduled 8, Actual 17. Retired 12/04 heavy duty: Schedule 8, Actual 18. Retired 12/03 heavy duty: Scheduled 8, Actual 19.		1991 Orions (retired at 14 years) - replacement decision driven by increasing maintenance - does not use mileages. Goshen coach (retired at 6 years, averaged 150,000 miles). Vehicles could not stand up to fixed route services.	(1) 30 1993 TMC CNG (retired 03/2005) - Retired 6 month early due to CNG equip outdated. 1986 Gilligs Phantoms (retired 9/2005) - kept for contingency and for use by local PD.	1984 35 Foot Orion (retired June 2006) age 22 years and with over 800,000 miles; 1985 Orion (retired August 2006) age 21 years and with 892,625 miles
Drivers of Retirement Policy	In order of priority: Capital funding, vehicle maintenance, other-ridership, physical condition/QOS.	Agency Duty Cycle (need to specify vehicles to operate with heavy-duty) and Capital Funding (mainly the LACK of alternative funding option). Does not use average fleet age or percent over age due to lack of funding.	Physical Cond/QOS, agency duty cycle (which is low/moderate), veh. Maintenance, cap funds	(1) Cap. Funds, (2) Condition/QOS, (3) Maintenance, (4) Duty Cycle, (5) Weather/Road, (6) FTA reqs.	Availability of capital funding; FTA minimum requirements	Condition/QOS, Maintenance, Capital Funding, FTA ages	FTA retirement ages; OTHER: MD MTA procurement cycle is slow (Frederick purchases most vehicles through the state). Significant lag between replacement order and vehicle delivery, state rarely provides as many vehicles as requested.	Maintenance, Capital Funding, FTA minimums. (QOS can be attained independent of age)	Physical condition, duty-cycle, maintenance requirements, and capital funding availability

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
General Experience - Mid-Life Overhaul									
Perform mid-life overhaul (y/n)	Yes	Yes, at 6 and 12 years. With further decline in provincial funding, revise overhaul program established at 9-10 years	No; tried back in 1992/1993 and found not cost effective. Not effective likely due to easy duty (larger buses maintained by County)	Yes, planned but not always done - last up to 15 years. When not done, rehab activities are as needed or on component basis.	Yes	Sometimes (no due to funding and manpower)	No. Frederick is small agency; only perform basic vehicle maintenance on-site. Engine/transmission replacements are contracted out. No other scheduled rehab performed	No, on an as-needed basis.	No
Components included in overhaul; cost of overhaul	Engine and major components (transmission, brakes, a/c): avg. $110k/vehicle	Engine, transmission plus extensive other components; avg. $100k/bus	NA	Power plant, paint, suspension, transmission, some structural. $100-120k per bus. Mini-overhaul 3-4 years: paint, interior, brakes, suspensions, shocks, airbags) = $30-40k. Geared towards performance, not extension; gain in reduction of corrective maintenance and road incidents	Rebuild power plant, A/C, brakes, steering, axels, body and frame, air tanks, limited wiring. Avg. cost of $173,000 bus		NA	NA	NA
Overhaul on Vehicle types	All 40-ft buses	All 40-ft. buses	NA	Heavy-duty	Heavy-duty	40-ft fixed route	NA	NA	NA
Additional years	Gets vehicles from 12 to 15 years, additional 150k miles	Extends 12-15-year bus to 18 years	NA	3-4 years if necessary to keep past 12 years, but done as corrective maintenance and keep incidents to minimum.	6 years	N/A	NA	NA	NA

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
Coordination of overhaul timing with expected life of major components (e.g., drive train replacement)	Coordinate with those that fail 6-8 years; looking into additional smaller overhauls (3,9 and 12)	With extension of major overhaul to 9-10 year, doing more component/mini overhauls during other years. Components with separate replacement cycles (brakes, steering, suspension) are on an ongoing basis (vs. one major overhaul); affects availability for service.	NA	Follow strategy of preventive maintenance. Use overhauls plus campaigns to do most maintenance as schedule (vs. corrective)	6-year midlife ensures continued performance of all components and subsystems	N/A, budget is major factor in whether midlife overhaul is performed	NA	NA	NA
FTA Minimum Service-life policy									
Impact of current FTA policy on retirement decisions (y/n)	No; however, later in interview, agency states some difficulty in reaching 12-year retirement age - did not retired but lighten duty	No (Canadian, no life constraint)	Used as basis for policy, schedule and actual retirement	No impact	12-year minimums result in 6-year midlife rehab at considerable capital expense.	Budget does not allow MTA to retire at 12, MTA attempts to retire at 13 yrs.	Submits vehicle replacement requests to MD MTA as vehicles meet minimums State requirements for smaller vehicles are slightly more strict.	No negative impact.	No. Vehicles exceed the FTA minimums in terms of both age and miles. Staff viewed this as a "positive" for the current service-life minimums
Would you retire earlier than the FTA minimums if you could?	No, agency retires later (15 years) due to Board policy	No funding to do so; Have kept vehicles longer than desired - would prefer to retire at 15, but no funding requires extending to 18 and further for procurement cycles. Have retired buses earlier than preferred (no	No impacts from retirement ages	No impact; exception of FTA funded 1983/1984 Grumman that could not handle NY duty and street conditions. Reimbursed FTA for portion (80%) - reason for use of State and City funds now! Early	Earlier; 8-year replacement would eliminate 6-year midlife rehab and ensure latest technology. Have not retired earlier than FTA mins.	Early possible, but budget constraint. Budget has forced longer service than desired due to absent funding/budget; Metro might entertain using shorter design lives. Has retired early (fire and beyond	In general, NO. Current minimums are appropriate. Would not retire sooner, but do like to retire close to minimum ages for maintenance issues (not QOS). Exceptions are Goshen and Thomas SLF,	Would not retire earlier in absence of requirements, and has not forced vehicles pass desired age. Have retired prior to FTA minimum (1993 TMC - due to CNG outdated). FTA approved early retirement	No, vehicles still have years/miles of remaining useful life after minimums have been attained

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
		FTA requirement) due to high failure rates and maintenance.		retirement affected other MTA projects and delayed procurements to refund those projects		economical repair)	which have provided problems. Goshens keep longer than desired (are unreliable and unfit for fixed service)		
Does your state have a minimum vehicle life policy?	No	No	Yes: same for larger vehicles, more years/miles for smaller	Yes, 7 years to cover all bus types	No	No	Yes (more strict than FTA minimums on smaller vehicles).	Not stated	Yes, same as FTA minimums.
Recommendations	Options for agencies; inclusion of rehab costs as reimbursable; extended warranties as reimbursable.	Suggest shorter useful life is NOT feasible for heavy-duty operations and procurement methods; Minimum age/mileage should be increased to 12,15,18,20 and 24 years. FTA classification be revised for rehab costs to be included.	No, current minimums are appropriate. Cannot judge appropriateness for smaller since they were recently purchased (previously contracted)	Makes sense to provide options; mileage looks high on annual average, should include rebuild costs as capital reimbursement (improve maintenance), stipulations on use of FTA funds for rebuild; use testing to pre-qualify buses, higher-level specs from "White Book."	Reduce minimum age/mileage to reduce maintenance costs. Change 12-year 500,000-mile category for 40-ft heavy duty to 8-year 300,000 miles.	Allow more discretion on buses not performing at optimum level. In general, age is acceptable. No changes.	Retirement minimums are OK, extending them would be a problem due to increasing maintenance.	No, current minimums are appropriate.	Maintain current policy
Vehicle Life Classes									
Opinions on the usefulness and applicability of the current classification	FTA should provide options for each vehicle type; make rehab and warranty reimbursable; longer life	Mainly focus on heavy-duty buses; maybe extend heavy-duty specs to smaller buses too	No	Mileage seems high (calculate avg. annual mileage and apply to each option consistently).	Useful, but redefine to include 8-year, 300,000-mile heavy duty vehicles.	N/A	Retirement minimums are OK, extending them would be a problem due to increasing maintenance.	No revisions/reductions/increases to minimums.	They are good. They allow for the purchase of a quality product and still provide reasonable replacement for high-volume

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
	shorter vehicles would be good, but are the required components & structure available??								areas.
1st Option (more durable, longer lasting vehicles)	Not right now; possibly in future	BRT vehicles not considered yet; have developed longer life vehicle specs with NYCT, WMATA and MBTA focused on stainless steel structure, composite panels and extensive rust protection	Only if other features come in, not just for the sake of durability	Yes in terms of durability, duty cycle places great strain on buses. Stainless steel is key to this.	No	If such vehicles truly had an extended vehicle life, METRO is very hard on vehicles, and struggle to get past 12 yrs.	No, not appropriate for market; concern of increasing maintenance costs and decreased reliability and service quality.	Yes	No. We are not in a high-volume service corridor and a longer life vehicle would only put us behind in technological advancements that are of benefit for safety and operating costs
2nd Option (less durable, shorter life vehicles)	Interesting, but do not see benefits. Component life is typically 6-8 yrs - would have to be in this range	No, do not believe can handle heavy-duty cycles	Skeptical that vehicle can be constructed with cost savings to make it cost effective option. Concern over increase of cost and effort of procurement process.	Would not apply to NYCT duty cycles	No. Looking for same heavy-duty vehicle with an 8 year minimum life requirement	Metro is hard on vehicles; could work if vehicles were suitably durable.	No, current age/mileage requirements are preferred. Concern: reduced life = reduce safety/reliability/durability. Consider life expectancy of vehicle structure and components.	No revisions/reductions/increases to minimums.	Our experience with shorter-life, medium duty equipment has been negative. Increased operating and repair costs for the agency; more service disruptions and increased passenger dissatisfaction
3rd Option (allow agencies to replace vehicles as needed, relying upon funding formula constraints to limit fleet replacement activities)	Currently done by agency (15-year, major overhaul - considering mini overhauls in between). Would not do anything different	Does not affect agency (Canadian), but believe this is best way		Yes, but concern about capabilities of other agencies	No objection	Reasonable.		Should be done as an industry to cause a change in life expectancy of buses.	If funding match were changed to 50/50, 60/40, 70/30, 80/20, 90/10…based on equipment age / mileage, it would encourage prudent maintenance and vehicle replacement practices

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
4th Option (consisting of up to three different options of minimum retirement ages / mileages for each vehicle category, plus pre-defined rehabilitation requirements for each option.)	Interesting, but not appropriate to 40-ft and with agency policies; would not alter procurement decisions; would probably require incentive	No, only do longer life durable procurements (no impacts to current procurement decisions); Heavy-duty 10-year option not useful - others OK (no experience with light-duty). Agency would require additional federal/provincial funding	Interesting but skeptical. Rehab provisions are of no interest (no rehab performed). Concern over capacity of "rehab vendors" to meet increased demand and how rehab would be monitored and approved by FTA	Yes, like idea of options within consistent structure. Procurement decisions not affected - would like to consider 15-18 year options. Suggestion to reduce annual miles.	No, but suggest 8-year option.	Yes; alter procurement by more evaluation of trade-offs (age vs. operating costs); Need to consider impact of sustaining vehicles on emissions. Challenge: Need to have good understanding of how increased age decreases QOS. Incentives: could encourage our procurement decisions to look at alternative procurement scenarios.	Like having more options. Interest in having rehab option but concern how smaller agencies might implement option (do not do rehabs, typically contracted out). Who would perform rehabs and to what level. General interest in longer, more reliable vehicles, no interest in short life (perceived as cheaper components/reliability/safety)	No; low price/bid not conducive to best value for rolling stock.	No. The mileages are too high for replacement @ the percentage of match funds. We would be always running older, behind the technological curve coaches.
Effects of earlier bus replacement	No price benefits with shorter life; components do not allow for shorter/longer life; sourcing of parts for older vehicles is a BIG issue (longer life would increase problem)	Potentially more inventory control issues	Vague answer		Reduced maintenance costs, fuel costs, midlife rehab costs, emissions and increased customer satisfaction. No negative impacts	Shortens time to adopt new techn. (improved passenger amenities, efficient/lower emissions). Faster replacement means passengers benefit from newer equipment.	Cheaper buses = cheaper components = decreased reliability.		

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
Extend Minimum Life: Additional costs, including maintenance	Little effect on current costs (policy is already at 15); some financial impacts from procurements that couldn't make 15 year. Maintenance expenses would increase because of increase in mean distance between failures	Increased need for mini overhauls of components; slightly increase - planned component overhauls helping to maintain reliability and cost increases.	Increased maintenance cost and demand more durable vehicles from manufacturers		Maintenance expenses would increase, approx. 8% per year.	Addition of mid-life overhaul program; higher rate of catastrophic failures and corresponding operating costs. Costs increase: Mid-life overhaul $50-$100k, plus 10-50% higher maintenance cost (higher component and structural failures). Reliability reduced by 10-25%	Increased maintenance expenses. Passenger complaints also an issue (80% are work trips, 50% are captive riders)	Higher maintenance costs (corrosion could cause additional costs). Running repair costs could go up 10-15%, plus paint, cosmetic and corrosion repair to be evaluated for feasibility.	Would limit ability to purchase replacement coaches when funding was available; could force us to use antiquated less passenger friendly equipment and limit our ability to expand future service; maintenance costs would increase
Energy/Emissions impacts of earlier bus replacement	Slight increase in emissions, but larger increases from newer engine performance; Slight reductions in energy efficiency from original engine performance, but larger reductions from newer engine performances;	Have not seen increase or decrease; emissions not changing, energy nearly the same, no decline in performance.			Energy/Emissions would increase by 8% a year	Difficult to quantify. Energy efficiency: No, unless significant breakthrough in engine efficiency.		No on emissions, No on energy, newer engines are getting less mpg.	New technology is leading the charge to produce emissions free vehicles.; Not all older fleets will be able to retrofit to current and future EPA requirements

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
Other options for FTA to consider					Consider an 8-year minimum life option for heavy-duty larger buses, keep same level of quality (no decrease in quality). Would improve customer satisfaction, reliability, maintenance, latest technologies, emissions, fuel economy, educated workforce, positive community perception	Other options: Large regional transit agencies should be allowed to use proposed "pooled procurement" approach. This allows for 90% reimbursement. They would have to allow other regional operators to piggy-back on those procurements	Supports development of more durable, better quality, "10-year" bus (30-ft Orions are too large for downtown); desire for sturdy/durable short vehicle capable of extended "heavy" duty.	No impact on performance, maintenance plans would be tailored to bus needs.	Base FTA replacement schedules on service/agency type; urban, rural or non-profit; high-volume or low-volume. Based on these criteria, use variable agency match as the incentive to regulate quality maintenance and vehicle life.
Vehicle Components – Impacts of Life Expectancy									
Is maintainability / life expectancy of vehicle components a key retirement driver	Structural members determine life (reason to retire early) - everything else is replaceable (choice is replace vs. maintain)	Yes; CNG buses had to be retired at 12 due to high maintenance - don't know for hybrids (expect same as diesel); AC drives rebuild every 5 years on hybrids; Expect 500k miles on engine; Structural corrosion is limited by stainless steel, composite panels and rust prevention efforts	No, although concerns of general maintainability are a factor		No. Retirement is aged-based, not component-based. No component is durable beyond expected 12-years.	Yes.	Increasing maintenance and decreasing reliability is primary concern of age.	Yes, if corrosion is bad then consider early replacement.	Yes.

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
Components important to replacement decisions	Heavy-Duty: Electrical system (tends to go at 15); Engine and transmission the most expensive	Body structure, panels, corrosive protection, drive train and suspension on low-floor vehicles			Components changed on corrective/failure basis: Engines, transmission, alternators, starters, A/C compressors, air compressors, fuel injectors, AVL assemblies.		Interviewee's area not capable of answer; general sense that no parts in particular cause problems, but typically a range of components become less reliable.	Structure, axes, exterior skin, floor; corrosion; Other issues typically resolved with proper maintenance.	Body condition (i.e. leaking, excessive corrosion); power plant; electronics failure; structural wear and integrity
Components with no impact on retirement decisions		Doors, brakes, controls, windows, bumpers and interior replaced on a corrective basis. Doors, brakes and controls below that expected							Brakes, seats, stanchions, suspension, steering, transmission, paint, flooring, signage and wheelchair lifts
Other Issues affecting Procurement Process									
Current procurement policy for your agency	Best value negotiated based on price and other factors (low bid no good = lower quality)	Low bid with tight specifications and brand requirements. No bids have been fully compliant. Needed to negotiate relative compliance to specs. Tight specifications focused on body, undercarriage and panels are more important in procurement	RFP - price is only 10% of evaluation; great emphasis on quality (evaluated by quality selection committee)		Low-bid	IFB & RFP. More advanced vehicles are usually purchased via negotiated procurement. Believe procurement process has an effect on quality and expected life of bus	Purchase through the state (MD MTA). Have "piggy backed" some procurements with other counties (low bid)	Best value, RFP	Piggy-back on existing FTA approved bids

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
Impact of procurement methods on useful life	Big impact on useful life due to higher quality product received (vs. low bid = lower quality)	Impacts on longer-life requirements			Precludes known quality components	No impacts		Best value, as lowest bid does not always mean best value as the life expectancy could be worse. Believes procurement process has impact on quality and expected life of bus	Yes. If the bid options necessary for our service conditions are not available and yet we need to purchase the vehicle; that vehicle will be retired at the FTA minimum as opposed to exceeding the FTA replacement criteria
Suggestions	Enhance standard bus procurement guidelines to include performance-based specs and include more options/alternatives. Current specs are too prescriptive					If there was a good way to accurately estimate vehicle life cycle costs for certain vehicles, especially composite vehicles.			Proviso for small agencies to add options necessary to their service area or require RFP agencies to include in bids as many allowable options as possible. It is not unusual to see a large agency produce specs with only their agency needs in mind and attach no options lists

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
Impact of Buy America on useful life	Yes, structural members drive useful life and Buy America does limit/affect how a manufacturer develops structure. Buy America also limits design improvements due to limited market/competition for change	No requirements in Canada, but do limit European content to 20% due to their use of low-carbon steel. Have restricted use of frame design and manufacture from European suppliers.	Only applies to state-funded vehicles (which is a minority)		Reduce heavy-duty to 8 years	Somewhat true. Most Buy America compliant bus manuf build their bus structures outside of US, though don't know whether this has a qualitative impact. Given how small the US bus industry has become, the current provisions may be restricting how quickly US Transit Properties can adopt the latest international technologies.	Not qualified to answer (purchase through state)	Useful life is dependent upon procuring agency to know what they need and how to maintain.	The Buy-America requirements increase the cost of a vehicle without necessarily increasing its useful life. Lowering the Buy-America percentage will allow manufacturers to produce vehicles at a lower cost with the same or better quality. Example: Mercedes-Benz.
Altoona Testing - Use of Testing Results	Yes, use them, but not rigorous enough; Results included in price and other factor measurements for bid (weighed).. More agencies should use results, recommend providing actual test results (vs. pass/fail)	Yes, use the bus testing results in the evaluation and require the New York drive files from the B-35 bus route shaker test	Not directly		Yes, new purchasing is a in-house/consultant function; consultants use Altoona when advising clients or writing specs. Data could be organized to establish quality ratings as a guide in achieving minimum life requirements. Suggestion: Expand Altoona testing to include quality rating system for buses.	Yes; reports are reviewed and discussed with vendors prior to all new bus deliveries.	Not qualified to answer (purchase through state)	Yes, testing is required by APTA guidelines. More testing as in Altoona will provide better information for agencies (but who will pay?)	The Altoona testing is done in such a manner that it is of no practical value to maintenance personnel or to operations for passenger safety; Competition between manufacturers is the best for achieving a quality long-life product. Altoona simply adds costs passed on to the transit system

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
"White Book"									
Adapt guidelines to reflect alternative useful life options?	Very good idea; guidelines should be performance-based and offer alternatives/options for each components; include extended warranties as just warranties. Need to develop plans to respond to many design exceptions	Yes, and use more onerous specs from Toronto, NYCT.			See similar options for medium/light duty. Yes	Only if there was an understanding that 10 years in heavy, urban transit can be far more severe than 15 in suburban.	Not qualified to answer (purchase through state)	Yes, as long as today's 12-year do not become tomorrow's 10-year	
Would you consider using design specification for an FTA approved 10 year bus?	No, due to 15-year Board policy; If policy changes, then maybe for limited specialty fleet like downtown circulators	No.			If bus components remained at 12-year level	Yes, but not necessarily agree that a 15-year bus for suburban use got more funding than a 10-year bus for urban use.		Maybe	
Would you consider using design specification for an FTA approved 15 year bus?	Yes, this way now; would appreciate more work on bus specs for longer life buses	Already use; No experience in medium or light duty, but sounds ok.			No	I have yet to see a bus that will hold up well to 15 years service in heavy duty urban environment.	No, 15 years is too long.	Yes	
Would you consider similar useful life options for medium and light vehicles?	Do not use except for paratransit	No experience, but sounds ok			Yes	Not applicable		No, the light-duty market is OK.	

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
Use of useful life exempt FTA demonstration programs to advance adoption of new technologies	Good idea to help move state of industry forward; use to introduce new technologies	Alternatives of interest to TTC are procurement of prototype buses from several manufactures to test in service before selection of supplier. This is similar to NYCT program. Also, maybe lease buses to test new manufacturer or model in operations before authorizing/approving for bid.	RideOn is too small, not in-depth experience with maintenance.		No	Yes	No as a smaller agency; small staff, limited resources, limited capability to support technologies.	Yes	No
Bus Procurement Difficulties									
Difficulties keeping a vehicle in service through the minimum life requirement?	Yes, used vehicles for lighter duty, shorter service spans, then moved to spare and contingency until 12-year	Yes, 150 Orion 6 CNG buses that were unreliable and high maintenance. Retired at 12-years, trouble getting to that 12 years.			Yes, premature failure of cradles and frames	Yes, Methanol TMC buses in 1992 need to be converted to diesel to run reliably.	Goshens and Thomas SPFs, found to be unreliable for fixed route; now use for limited service on lower duty cycles or low ridership routes. This increases service hours of more reliable vehicles.	Yes, TMC CNG buses (outdated CNG)	No
Requested waiver from the service-life policy?	Yes, but rejected	Not applicable			No	Not in recent memory except for a handful of accident buses.	No		No

Issue Area	WMATA (Washington)	Toronto Transit	Montgomery Co. Ride-On	New York City Transit	MBTA (Boston)	LA MTA (Los Angeles)	Frederick Co.	Capital Metro (Austin, TX)	Jefferson Transit
Reaction to creation of a "Lemon Law" for problem vehicles	Good concept, difficult to quality/enforce. Suggest for this to work, there should be an industry-wide finding of poor performance (not just agency) - exclude them from counting against spare fleet, allow agency to decide optimum retirement, and ensure remaining years funding rolled into next procurement (perhaps with higher local funding reqs)..	Yes. Had New Flyer and Icarus artic space frame corrosion problem and structural failures that had to be expensively maintained to make 12-years.	Great!		Yes, under constraint that manufactures should be compelled to ensure the structural integrity and durability of bus frames with min. maintenance requirements over the min life of the vehicle.	Yes, if it were necessary; Option should not be used 1) following completion of normal warranty period, 2) when the annual operating cost or fleet reliability are substantially different than the rest of an agency's fleet.	Yes, but need to define conditions under which it would be applicable. Suggest really only apply to limited and fairly serious conditions. Own/Self problems not sufficiently problematic to warrant use of option.	Yes, if responsible party (bus supplier) is dealt with.	Yes
Other Suggestions and or Comments						Policies need to consider difference between large urban operators and small suburban or rural operators.			

APPENDIX B. SUMMARY OF VEHICLE MANUFACTURER SURVEY

Issue Area	Orion Bus Industries	Millennium Transit	Optima Bus Corporation
General Life Expectations			
Current buses manufactured	Two models, 30-40 length, 44-47 passengers. Minimum life: 12 years; Expected: 18 years. Altoona tested.	No inventory provided.	Three models: (1) Opus Under 30', 30.5' length, 23-27 passengers. Minimum, scheduled, manuf. estimated life of 12 years. (2) Opus Under 35', 35' length, 31 passengers. Minimum, scheduled and manuf. estimated life of 12 years. (3) American Heritage Streetcar, 28.75' length, 28 passengers. Minimum, scheduled, and manuf. estimated life of 12 years.
Marketing based on FTA categories (y/n)	Yes	Yes, vehicles in 12-year service-life category tested and sold.	Yes
Vehicles not subjected to Bus Testing Regulation	Yes, the Sprinter Van, bought by smaller agencies with local money.	Yes and No. Same buses are sold in Canada, which do not have to meet regulation (sell based on service record).	Yes, FTA granted waiver to perform additional testing on "Opus Under 35'" vehicles.
Specific expected-life characteristics	18-year vehicles in Canada. Agency customers ask for longer warranty period, and extensive corrosion resistance in Eastern part of country (high salt environment).	No, transit operators want buses that hold-up (argue their environment is the most severe). Not all 12-year buses created equal (New York does not purchase Bluebirds tested at 12-year, does not hold up to NY environment).	Yes, request from agency customers is for heavy-duty transit buses, normally aligned with FTA minimums. However, they may choose to keep vehicles in service longer. Primary determinants of vehicle retirement age: operating environment and duty cycle, maintenance needs above 12-year age.
Recommendation of mid-life overhaul (y/n)	Do not recommend on chassis. Cannot predict future condition of vehicle, depends on duty, environment, maintenance, etc.	Do not recommend or get involved. No benefits to manufacturer if agency does or does not perform overhaul - overhaul funds go to component vendors.	Recommend following vehicle and component maintenance schedule. Need for mid-life overhaul dependent on duty cycle of vehicle.
Components included in overhaul recommendation	No on chassis. Engine and transmission should be replaced. Manufacturer provides few unique parts for overhaul; most parts are purchased directly from vendor.	Provide few unique parts for overhaul, but most parts are purchased directly from vendors.	Engines, transmission, suspension and axle (approx. cost of overhaul or update is a little over $18k)
FTA Minimum Requirements			
Impacts by FTA minimums (design driver)	Yes, especially the 12-year category. Category fundamentally drives design; 12-year is heavy-duty benchmark.	Buses built to meet FTA service-life requirements. Impacts would be from changes: (1) sell less buses if increased to 15 years, and (2) be put in competition with lighter-bus manufacturers if requirements decreased to 8 years. Corrosion requirements dictate use of stainless steel and aluminum instead of mild steel.	Yes, design and durability affected by minimums. Compete in heavy-duty market, thus need to design for 12-year/500,000-mile vehicles. Build relationship with agency as vehicles sold approach minimum ages. Also affects sales of parts, after components fail past warranty period but before reaching minimum age. Drive design by specifying service-life requirements to component suppliers; chassis and body durability and testing requirements of category establish engineering design levels for load, stress and fatigue criteria.

Issue Area	Orion Bus Industries	Millennium Transit	Optima Bus Corporation
Vehicles or components affected	Components not replaceable or cannot be rebuilt - such as chassis.	Structure required to last 12 years without class 1 or 2 failures. Warranty periods depends on component manufacturers. Engine manufacturers charger higher for 12-year warranty (i.e., price of 4 engines)	Chassis, body, axles, suspension, engine, transmission, floor, crash worthiness and air conditioner.
Customer requests different than FTA minimums	Canada requests 18-year vehicles. Others want a 15-year life for chassis, CNG tanks with 15 to 20-year service life.	No.	No.
Recommendations/Changes to current FTA minimums	There has been debate over "12-year" build vehicles not durable enough (ensure testing is within right category). Altoona testing should be more (stress the durability more) and have more of a pass/fail aspect.	No changes. Lower minimums would put company in competition with smaller-bus manufacturers. Increase of service life would result in less vehicles sold. Do not believe longer, more durable bus can be manufactured. Already build most durable buses out there.	No changes recommended to current minimums. Classifications should be revised if tied directly to Altoona Bus Testing, and monitor/regulation should be revised (less arbitrary, subjective method). FTA minimum retirement ages are arbitrary classifications, driven by Altoona testing. Testing not always reliable benchmark as manufacturers choose category to test under. Vehicles are also not given rating. Testing not monitored by FTA or governing body. In the eyes of the industry, Altoona bus testing drives life expectancy of buses, although transit operators cannot review testing reports. Bus testing reports should be a determining factor because it gives insight into durability and reliability (failure types, problems, etc.).
New Vehicle Life Classes			
Current usefulness/applicability of vehicle classification	Categories are not definite enough. They conflict with EPA definitions and weight classes are too loose.	It is what it is.	Minimum retirement age based on Altoona Bus Testing: no pass/fail assignment, manufacturers choose classification to test under. Vehicles are given classification when it completes test, regardless of length of test time or durability. This gives marketing edge, which forces manufacturers to test at highest possible classification regardless of vehicle's quality or durability.
Option 1: Longer-life vehicles			
Interest in manufacturing	Yes	No, do not believe more durable buses can be manufactured.	No, components would not survive longer minimum retirement ages. In most cases, component manufacturers cannot produce more durable components. Also, duty cycle plays a key role in retirement decisions. Larger, specialized BRT vehicles would more likely have strenuous duty cycle, affecting ability to meet longer-life requirement.
Characteristics	Characteristics would include being inherently resistant to corrosion, and have a higher GVW (over 33,000 lbs category).		Component suppliers would have to provide longer, more durable components. Longer-life vehicle would be heavier (heavy-duty parts or higher-cost materials), would reduce fuel economy and would increase purchase price.

Issue Area	Orion Bus Industries	Millennium Transit	Optima Bus Corporation
Challenges	Challenges would be to encourage a modular design (beneficial to operators). Same bus in different lengths, the weight class is the discriminator. Rebuild cycles would create problems with part availabilities such as engine parts.	Could not support today's technology for long periods (engines, software).	Cannot increase life-expectancy of components, increase purchase price.
Option 2: Shorter-life vehicles			
Interest in manufacturing	Yes - the need of transit operators differ, especially duty cycles and suburban/urban areas.	No, focus is on 12-year buses. Less desirable would mean eliminating options, use of mild steel, less expensive components. European design methodology previously used for low-floor bus - did not pass testing.	Not our market niche.
Characteristics	Lighter weight, lower-cost components, lower expectation of durability, maybe lighter duty engine.	Truck engines and axles, cheap seats, medium heavy-duty engines.	Not our market niche.
Challenges	Establishing market for these vehicles.	Getting cost out from components, not structure.	Not our market niche.
Other options	None.	None.	New vehicle types: hybrid electric. Properties: diesel or gasoline engine that rotates a generator, providing electric power to electric mothers through either batteries or ultra-capacitors to an electric motor driving the rear wheels.
Vehicle Components			
Effects of maintainability/life-expectancy of vehicle component on service life	Structure dictates life of vehicle - retirement comes as structure cannot be economically repaired.	Yes, specifically the major component systems.	Yes, maintainability and availability of parts plays a key role in retirement decision. Another driver of retirement is the perception of ridership and willingness to ride older vehicles (vs. newer vehicles that may attract more riders).
Components that impact service life	Structure, chassis.	Engine (CNGs do not last as long as diesel), transmission, destination signs, axles, HVAC, CNG tanks	No specific components listed. Overall maintainability and quality of vehicle impacts retirement decision.
Components that do not impact service life	Wear items, glass, moving parts, wiring harness.	Seats, hand rail-stanchions, radios, destination signs, fare box, windows - changed as needed.	Customers have transferred the following items from 15-year old vehicles to new vehicles in all of our models: fare boxes, radios and voice announcement systems.
Challenges to vehicle components with longer vehicles	No challenges to longer-life vehicles - already build 18-year vehicles.	Challenges to longer-life: no change to engine warranty by engine manufacturers, batteries on hybrids.	Parts becoming obsolescent as a driving factor. Challenges of longer-life vehicles to the following components affect all models: engine, transmissions, axles, lack of stainless steel chassis, suspension package, fiberglass components, electronic systems (including wiring), HVAC system, brakes, air system, alternators, and doors (and door controls).

Issue Area	Orion Bus Industries	Millennium Transit	Optima Bus Corporation
Challenges to vehicle components with shorter vehicles	Challenges to shorter-life vehicles: take out cost with reduced service life, smaller engines, lighter axle rating.	Challenges to shorter-life vehicles: de-rating components (use lighter-duty components from automotive industry), mild steel structure (if benign operating environment was certain).	Downgrade of design of each vehicle. Vehicles have been designed for 12-year/500,000-miles; mindset of industry demand for this vehicle type would have to change if life expectancy decreased. No specific components stated.
Component life-expectancy driven by other markets	Yes - axles, brakes, engines (but not transmission).	Yes - engine, transmission, HVAC (by refrigerator truck market), axles (drop axles not specific to bus market - off road is larger market).	

APPENDIX C. ENGINEERING INTERVIEWS

Questions	CATS (Charlotte, NC)	Golden Gate Transit (San Francisco, CA)	Harris County Metro (Houston, TX)	LA MTA (Los Angeles, CA)	Lane Transit District (Eugene, OR)	MUNI (San Francisco, CA)	WMATA (Washington, DC)
Service-life policy and Targets							
How does your agency define the useful life?	By age and then mileage	Useful life is determined primarily by age but GGT will keep buses longer if condition is good	Useful life is FTA 12 year	The MTA uses the FTA definition of useful life: 500,000 miles, 12 years, 40,000 miles/year	LTD defines useful life according to FTA's service life criteria	Muni uses 12 years as economic useful life of buses. Muni's buses are often in service for up to 16 years	FTA and APTA New Bus Procurement Guidelines
Does your agency have a target useful life for your standard 40 foot transit buses? What is it for smaller buses?	Target is for 12 years but can get 15 years from heavy-duty buses. The target is 5 years/150,000 miles for cutaways	Target is 12 years. Buses are typically in-service for 14 years. OTR coaches are kept for 16 years	Target is 12 years	13 years or 500,000 miles	LTD targets 15-year service life. Smaller buses are replaced at 7-year	Same as above	Policy is 15 years
Life Extending Practices: What are they?							
What life extending practices does your agency utilize if any?				MTA uses an extensive maintenance program to maintain its fleet of 2,400 buses	Nothing on structure	Midlife overhauls of engines, flooring and other components as needed, fleet wide campaigns as necessary (battery replacement, etc).	Preventive maintenance (PM) and Vehicle overhaul (VOH) programs
Preventive maintenance?	PMs are done by mileage at 6K and 12K. As the Gillig Phantoms aged, they were required to have a 3K PM due to engine issues	Rigorous PM program which includes engine oil and transmission fluid analysis at each oil change interval, providing early warning of problems		Mid-life overhauls: interiors, suspension, paint, engine.	Basic		Daily – pretrip, 3,000 mile – Minor mechanical , 12,000 mile - Major mechanical PM inspections, 18-day interior housecleaning
Specify corrosion resistant structure materials (aluminum, stainless steel)	New bus specification are for a stainless steel structure	Do not spec entire stainless steel bus, but will specify at critical areas such as power train mounting locations	Do not spec stainless steel		None. Eugene doesn't have issues with corrosion	Buses speced to be built with corrosion resistant materials but allow the bus builder to specify brand	Stainless steel & protected carbon steel
Specify undercoating			Undercoating is included in specification		None		Interior tube rust inhibitor; Tectyl 506, Waxoy or equal. Undercarriage; Tectyl 127 CG or equal

Questions	CATS (Charlotte, NC)	Golden Gate Transit (San Francisco, CA)	Harris County Metro (Houston, TX)	LA MTA (Los Angeles, CA)	Lane Transit District (Eugene, OR)	MUNI (San Francisco, CA)	WMATA (Washington, DC)
Warranty. What are your warranty requirements for a 40' transit bus?							
Engine	2 year standard warranty (new spec calls for 5 year extended warranty)	5 year extended warranty	2 year standard warranty: METRO does not use extended warranties as FTA does not fund	2 year standard warranty	Standard 2-year. On new engine designs, LTD purchases extended 5-year warranties		5 years / 300,000 miles
Transmission	1 year standard warranty (new spec calls for 5 year extended warranty)	5 year extended warranty	2 year standard warranty	2 year standard warranty	Same as engine		5 years / 300,000 miles
Bus structure		12 year corrosion warranty		2 year standard warranty	If more than 10% failure rate, considered fleet defect per specification		40' bus – 12 years / 500,000 miles
Procurement and Legislation							
Do you think the low bid process has impacted the expected useful life of transit buses and vans?	CATS does not use low bid, they use a Best Value negotiated procurement.	Yes – bus builders must use lower cost/lower quality materials to compete and/or use lower cost/less qualified labor to assemble bus. GGT has used a negotiated procurement on their last vehicle purchase	Yes – they had a very bad experience with Neoplan which was a low bid procurement	Yes, absolutely. The MTA has been burned by low bid processes.	Not if you have a tight specification. If your specification is tight, the manufacturer can not substitute inferior quality parts that could cause service life issues	Muni uses negotiated/best value method. In past electric trolley bus fleet procurement the low bid winner was an Eastern European manufacturer that typically had shorter life spans than North American customer expectations.	Yes. Negotiated procurements give more flexibility to acquire more reliable components and system
Do you think the Buy America ACT in any way impacts the expected useful life of transit buses and vans?	Limits choices, especially for BRT type vehicles. However this is not a current concern for CATS.	No	No – does not impact useful life		No negative impact. LTD's challenge is complying with the regulation in performing inspections and assuring component content source	There is not enough background data to know this.	
EPA Emissions?	CATS stated that this is a good thing. It has not influenced early retirement of buses, but has required retrofits to older buses	CARB regulations more stringent than EPA's. Resulted in small California transit bus engine market of only 400 engines per year, making these engines an expensive		MTA operates in the most restrictive regulatory environment. State EPA audits emissions twice per year	Diesel particulate filters on 2004 engine plugging prematurely causing excess back pressure. This back pressure is expected to reduce life of the engine. Too early to tell how much		

Questions	CATS (Charlotte, NC)	Golden Gate Transit (San Francisco, CA)	Harris County Metro (Houston, TX)	LA MTA (Los Angeles, CA)	Lane Transit District (Eugene, OR)	MUNI (San Francisco, CA)	WMATA (Washington, DC)
FTA ADA?	Has impacted facilities, but not vehicles	No			None	On a recent bus procurement, an ADA compliant wheelchair ramp was mechanically inferior to manufacture's standard ramp because the cables were tested and found more likely to fail in service	
FTA Bus Testing Regulation?		No			Good requirement. Helps assure the availability of quality products		
Impact of Service Environment / Vehicle Structure on Useful Life							
Have you had any issues in meeting the FTA 12 year minimum life requirement?	Have not had an issue with 40' buses.	No	Engine cradles with NABI buses were a problem – but were addressed by the manufacturer	No, as long as maintenance is performed, the MTA meets the 12 year life	No issues with meeting 12-year life.	No	Aggressive PM's and mid-life overhaul programs have allowed us to meet minimum life requirements for transit buses.
What is the primary determinant of the useful life of the structure (service environment, age, mileage)?	Mileage	Service environment. A unique Californian impact is the requirement to recycle bus wash water – this was found to be corrosive to the buses	Service environment. Buses on demanding service routes get beat up much more quickly than buses of similar age or mileage.	1) Construction 2) Environment. The MTA operates in a harsh environment. Every street has manhole storm drains that beat up the fleet on a daily basis.	Age, mileage, repair costs and safety issues	Muni's severe service environment (i.e. the topography)	Service environment, age, and mileage; plus life extending practices
To what extent does was your service environment the cause of early vehicle retirement?	Charlotte's service environment not a major determinant of useful life	GGT replaces buses at 12-14 years this is not necessarily because they are worn out	Results in cracking body, loosening of panels, more rattles	The environment is a key factor in the life of the fleet.	It doesn't. Mild temperature	Early failures are sometimes seen around the interfaces between suspension and frame or axle and suspension if not properly designed for the Muni topography	Service environment causing early retirement of the vehicle is highly unlikely.
Do you consider your service environment more severe, average, or less severe than the national average	Less severe to average (roads are in good shape, do not use salt, no snow)	Less severe to average	Average	More severe. The buses are abused by the environment, loads, and service demands	Less severe	Severe: Muni topography is unique and requires structure development is necessary and limited to a certain extent by foreign or domestic suppliers	Average to more severe due to winter salting of road surfaces

Questions	CATS (Charlotte, NC)	Golden Gate Transit (San Francisco, CA)	Harris County Metro (Houston, TX)	LA MTA (Los Angeles, CA)	Lane Transit District (Eugene, OR)	MUNI (San Francisco, CA)	WMATA (Washington, DC)
Different designs: Low Floor or Articulated							
Do you expect the useful life of low-floor vehicles to be less than or greater than standard buses?	Only expect 12 years from low floor buses, but could get 15 years from high floor buses	Have not run the low floor artics long enough to form an opinion	No	No issues	Too early to tell. Low floor buses require more frequent replacement of suspension parts	Hope and expect the same based on testing and analysis	Equal to standard bus
What about articulated vehicles?	Na				Recently purchased some New Flyer articulated buses. Too early to tell	Same as above	Equal to standard bus
What about for smaller cutaway and body on frame constructed buses?	Had a 5-year target but high mileage and demanding service made it difficult to achieve		METRO Lift vans were originally purchased to keep for 3 years – will keep for 5 years		No data	Muni does not employ these types of buses	
Planned/scheduled overhauls							
Do you perform a major mid-life rehab?	No	No. Repair / replace components as needed	No. Buses are fixed when broken	Sometimes (no due to funding and manpower)	No. LTD has studied, but decided it wasn't worth doing	No (just drive train). Flooring and other components as necessary	Mid life overhauls are performed to standard 40' 12-year bus at the 4 and 8-year interval
Do you perform engine / transmission overhauls at regular intervals?	No. Replace with rebuilt engine /transmission as needed. Typically swap out an engine at 200,000-300,000 miles (6-9 years).	GGT performs regular oil and fluid analysis for engines and transmissions. to identify pending engine/transmission problems	No. Will replace as needed. A bus will go through 2-3 engines and 3-4 transmissions over its life	Engines 250,000	Yes. Engine: 350k miles, Trans: 250k miles	Yes. Midlife	Engine and transmission overhauls are performed to standard 40' 12-year bus at the mid-life vehicle overhaul
Reliability of vehicles as age increases							
How significant are reliability issues as your vehicles approach the end of their useful life?	CATS is a young agency and it does not have long term service experience.	GGT has not seen a deterioration of vehicle reliability as vehicles age. This attributed to the PM program	Will see vehicles become more expensive to run as they age.	If the fleet is maintained, the life can be achieved.	Maintenance requirements do go up as age of vehicle increases	It varies from fleet type to fleet type	Vehicles approaching the end of their useful life are less reliable and more costly to maintain depending on the life extending practices employed
Do you have quantitative measures of reliability versus vehicle age?	Quarterly audits are performed that sample 25% of the fleet.		METRO tracks operating costs, not necessarily reliability. Buses are replaced when they are considered too expensive to operate		No. In process of switching to a new maintenance management system	Yes	No quantitative measures of vehicle reliability vs. age are employed at this time

Questions	CATS (Charlotte, NC)	Golden Gate Transit (San Francisco, CA)	Harris County Metro (Houston, TX)	LA MTA (Los Angeles, CA)	Lane Transit District (Eugene, OR)	MUNI (San Francisco, CA)	WMATA (Washington, DC)
Have you encountered issues sourcing replacement components for older buses?		Yes – this is always an issue	Yes – can no longer get parts for Neoplans and have problems sourcing parts for European OTR coaches. In contrast, older RTS buses kept in service for up to 18 years.	Yes. Example: Detroit Diesel has gone out of the transit bus business. Parts are no longer available	No. Oldest buses are 1991 Gilligs. Parts are available	Yes. This happens often with non-US supplied parts or if the bus builder or supplier goes out of business	New vehicle procurement contracts contain provisions that ensure support from the OEM for the life of the vehicle for items such as replacement parts
Alt-Fuels / and Hybrid Vehicles							
Has the useful life of alt fuels vehicles been less than standard diesel vehicles?	CATS has two Allison hybrids. There is concern that the extra weight may impact structure life	N/A. Will begin testing ethanol/diesel blend this year	No longer operate alternate fuel vehicles due to fueling station issues	Too early to tell. The CNG buses require 30% more manpower to maintain	Na	Too early to tell	We anticipate their useful life to be equal to standard bus.
Alternatively, how does their long-term maintainability compare with standard diesel vehicles?	The hybrid buses have very low maintenance. Both buses have exceeded 50% longer brake life and may also achieve longer oil change intervals.	N/A			Na	Too early to compare. Anticipate Muni may have to spend more time maintaining batteries	Equal to standard bus
New Technologies (AVL, AVM, APCs, Multiplexing, collision avoidance, cameras)							
How do you expect the long-term performance of vehicles with new technologies will compare with older, less technology oriented vehicles?		Will take more resources to maintain buses with additional equipment which will impact vehicle life if maintenance resources switched from vehicle PM to maintaining new technology			Too early to tell. Think of this type of equipment as separate from the bus. Upgrades are necessary as the equipment ages independent of the bus age.		Equal to standard bus
Alternatively, how do you expect their long-term maintainability to compare to standard vehicles with less equipment?		All of these systems result in higher electrical loads on the bus. It is expected that there will be electrical system problems previously not seen on standard buses with less equipment		Maintaining new technologies is a challenge. The staff are not trained on maintaining new technologies.		The more high tech features a bus has, the more failures are experienced. For example, a new fleet of electric trolley buses had significantly higher failure rates (lower mean distances between failures)	Equal to standard bus

Questions	CATS (Charlotte, NC)	Golden Gate Transit (San Francisco, CA)	Harris County Metro (Houston, TX)	LA MTA (Los Angeles, CA)	Lane Transit District (Eugene, OR)	MUNI (San Francisco, CA)	WMATA (Washington, DC)
Do you think reliability with these vehicles as they age will lead to the need for a greater spare fleet?	Anticipate that all these additional systems will have an impact on long-term life of electrical system due to the additional loads (have not had good reliability with cameras). Bus radio is the system that will keep a bus from going into service.	No. Currently buses are not held out of service if these systems (i.e. cameras) are not working	These technologies will increase maintenance costs but will not impact useful life		This may be an issue. Too early to tell	Yes	No, at this time we do not anticipate the need for a greater spare fleet due to reliability issues

APPENDIX D. MINIMUM LIFE-CYCLE COST METHODOLOGY

Chapter 7 presents the results of life-cycle cost analyses for each of the existing FTA minimum service-life categories. This appendix presents the methodology behind that analysis. Specifically, this discussion includes:

- Adjustment of participant agency supplied life-cycle cost data to reflect differences in annual fleet mileage
- Calculation of annualized cost factors
- Calculation of annualized vehicle acquisition, major component replacements and vehicle rehabilitation costs
- Regression analysis and annualization of O&M costs
- Calculation of total annualized costs.

Conversion of Participant Life-Cycle Costs to Reflect Differences in Annual Mileage

Agencies and vehicle manufacturers participating in this study supplied life cycle costs for major component replacements and rehabilitations of their transit vehicles (see Appendix E). Note, however, that the agencies providing data have annual mileages that are close to the national average (i.e., about 37,000 miles annually for a 12-year bus). Hence, while the timing of major component replacements for these agencies is representative of industry averages, they are not representative of agency fleets with lower or higher average annual mileages (e.g., 25,000 or 45,000 miles per vehicle per year respectively). As discussed in Chapter 6, agencies with lower annual fleet mileages per vehicle will be able to “stretch-out” their major component replacement cycles, while agencies with high annual mileages per vehicle will need to accelerate those cycles relative to operators with average fleet mileages.

Therefore, to conduct analyses considered representative of the nation’s full distribution of transit fleet mileages, the life-cycle cost data were adjusted to replicate the annual mileage of three separate annual vehicle mileage groups: 25,000 miles; 35,000 miles; and 45,000 miles. This adjustment was completed by first converting each component’s reported replacement *age* to a replacement *mileage* value based on the annual vehicle mileage of the operator supplying the data (i.e., multiply annual mileage by the component replacement age). Next, the replacement mileage values for each major component were used to determine the number of years that component would remain in service for fleets of varying annual average vehicle mileages. For example, if bus engine was determined to have roughly 250,000 miles between rebuilds, operators with only 25,000 miles in annual service only need to rebuild this engine in (250,000 miles) / (25,000 miles per year) = 10 years. In contrast, an agency operating its vehicles 45,000 miles each year will need to rebuild the engine in roughly 5.5 years.

Calculation of Annualized Cost Factors

Next, all vehicle costs—including the cost of vehicle acquisition, major component replacements, rehabilitation activities, and operating and maintenance (O&M) costs—need to be converted to an annualized basis. Annualizing tells us what the cost of each item would be, on a per year basis, if maintained in service for *x* years. Here, the value of the annualized cost can be calculated for any value of *x*, allowing determination of the annualized cost if the vehicle is owned for a period of time including 1 year, 2 years, 12 years, 18 years or more.

The factor for annualizing any cost is given by the following:

$$Annualized\ \ Cost\ \ Factor = \left(i / \left(1 - (1+i)^{-t}\right)\right)$$

Here, *t* is the number of years a component or vehicle is expected to remain in service and *i* is the discount rate (set to 7 percent for this analysis in compliance with OMB guidance). Note that the value of the annualized cost factor declines as the number of service years for a component increases (i.e., as the cost of that component is spread over an increasing number of service years). The values for the annualized cost factor at different years of service are presented in **Table D-1** (for the sake of comparison, Table D-1 also includes the value of 1/years, a frequently used but imprecise means of estimating annualized cost).

Table D-1

Annualization Factors (7.0%)

Years	Annualization Factor	1/Years
1	1.070	1.000
2	0.553	0.500
3	0.381	0.333
4	0.295	0.250
5	0.244	0.200
6	0.210	0.167
7	0.186	0.143
8	0.167	0.125
9	0.153	0.111
10	0.142	0.100
11	0.133	0.091
12	0.126	0.083
13	0.120	0.077
14	0.114	0.071
15	0.110	0.067
16	0.106	0.063
17	0.102	0.059
18	0.099	0.056
19	0.097	0.053
20	0.094	0.050

Calculation of Annualized Vehicle Acquisition, Major Component Replacement and Rehabilitation Costs

Next, these annualized cost factors were used to estimate the annualized value of all vehicle costs excluding O&M costs. This was merely a matter of annualizing the costs of vehicle acquisition, major component replacement, and rehabilitation activities using the annualization factors. This calculation is presented below. The double summation represents the discounted cost of all components (*x*) replaced as of vehicle age *t*. The value *Annualized Vehicle Cost* $_t$ then, provides a vehicle's total annualized cost value were that vehicle to be retired at age t (excluding O&M costs, which are considered next).

$$Annualized\ Vehicle\ Cost_t = \left(Vehicle\ Acquisition\ Cost + \sum\sum ComponentCost_{x,t}\right) * \left(i / \left(1 - (1+i)^{-t}\right)\right)$$

Regression Analysis and Annualization of O&M Costs

To this point, the analysis has excluded all vehicle O&M costs (e.g., fuel, preventive maintenance, and corrective maintenance). As noted in Chapter 6, O&M costs tend to increase overtime as vehicles age (i.e., as smaller parts begin to fail more regularly and fuel economy tends to decrease). The first step for this analysis was to develop regression models to model increasing O&M costs with increasing vehicle age. Unfortunately, this study did not have the resources required to conduct a detailed primary data collection effort of O&M costs by vehicle age for all five minimum service-life categories (and across multiple operators). For this reason, members of the study team drew upon an earlier analysis completed for a group of over 40 different small and medium sized bus operators based in Illinois. Together, these Illinois operators use each of the bus and van types represented by FTA's five minimum service-life categories and have multiple years of cost records for their vehicle fleets.

Analysis of Illinois O&M cost data yielded the following regression model of O&M cost per mile at vehicle life-to-date (LTD) mileage *x* for 40-foot buses (t-stats in parenthesis):

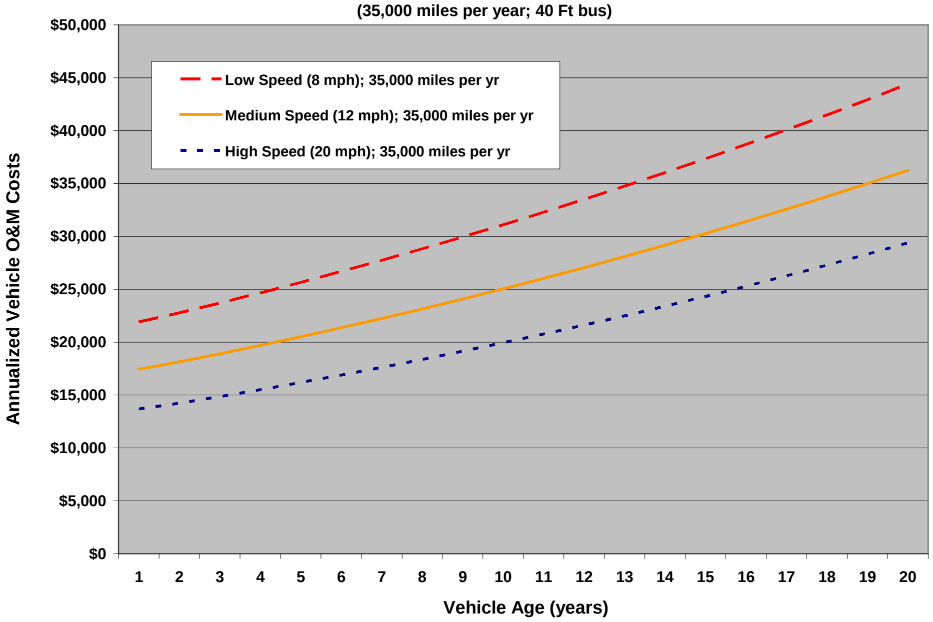
$$\begin{array}{lllll} \textit{Cost per mile at LTD mileage } x = & -0.783 & + 4.01\text{E-}07*(\textit{LTD Miles}) & - & 0.0317*(\text{Operating Speed}) \\ & (-9.41) & \quad (5.11) & & \quad (-5.27) \end{array}$$

The results of this model are presented in Figure D-1.

Figure D-1

Life Cycle Cost Profiles: Annualized O&M Costs

(35,000 miles per year; 40 Ft bus)



Finally, the equation above provides the cost per mile at different LTD mileages. However, to calculate the annualized values of O&M costs at age *t*, these LTD mileage based costs must be summed across the full life of the vehicle through age t, discounted and then annualized.

Calculation of Total Annualized Costs

Once O&M costs are added to the mix, the final calculation of total annualized cost is given by:

$$Annualized\,Vehicle\,Cost_t = \left(Vehicle\ Acquisition\ Cost + \sum\sum Component\,Cost_{x,t} + LTD\,O\,\&\,M\ Costs\right) * \left(i / \left(1 - (1+i)^{-t}\right)\right)$$

This analysis was then used to calculate total annualized cost at each age to determine the specific vehicle age at which life-cycle costs for each vehicle type are minimized.

APPENDIX E. HEAVY-DUTY VEHICLE LIFE-CYCLE COST ANALYSIS

Chapter 7 provides a high-level minimum life-cycle cost analysis for heavy-duty, 12-year transit buses. The presentation there is indented to provide the reader with a high-level overview of that analysis—yielding an understanding of the results but without focusing on the details of the analysis. In contrast, this appendix reproduces much of that presentation, this time providing an understanding of the details behind that analysis (including application of the minimum life-cycle cost analysis as presented in Appendix D).

Heavy Duty Vehicle Life-Cycle Cost Analysis

Using the analysis of national differences in operating characteristics and rehabilitation practices as presented in Chapter 6, this appendix develops a detailed life-cycle cost analysis of the 12-year, 40-foot vehicles that constitute the bulk of the nation’s bus transit fleets. This analysis is then used to identify that point in the vehicle life cycle when the sum total of all annualized costs (capital, operating, maintenance, and rehabilitation) is minimized. This minimum life-cycle cost point represents a financially optimal age to retire and replace a vehicle, in effect providing a measure of “economic useful life” (as distinguished from an engineering useful life or other measure). As expected, the point at which life-cycle costs are minimized can vary appreciably given differences in annual mileages, average operating speeds, and rehabilitation practices.

Specifically, this analysis considers the following life-cycle costs:

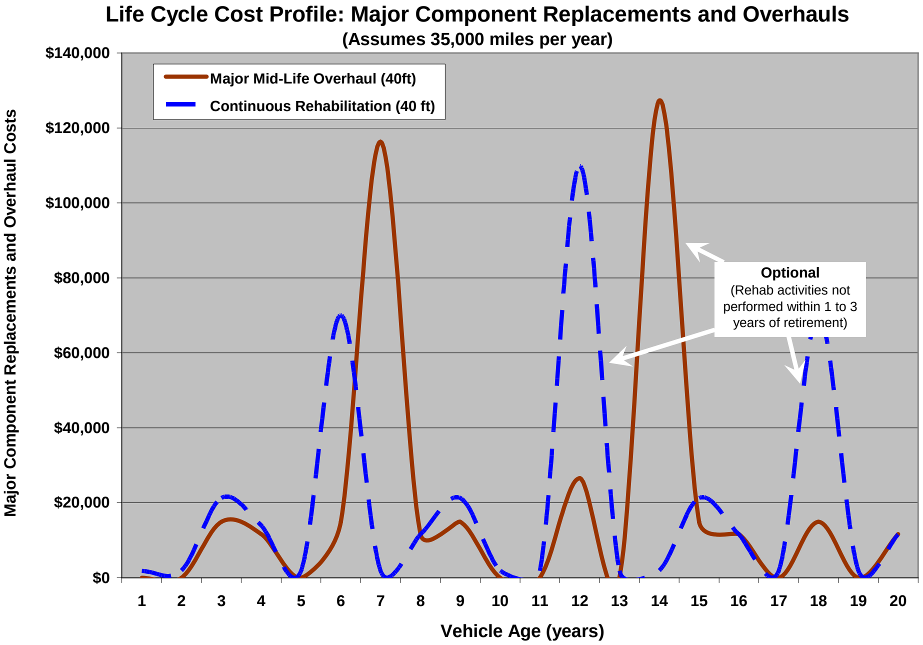
- **Acquisition Cost and Disposal Value:** Purchase cost plus related procurement costs as well as the expected sale price or scrap value of the used vehicle.
- **Expected Component Replacements and Mid-Life Overhaul Costs:** This includes the cost of all expected component replacements and rebuilds that naturally occur over the life of a vehicle (e.g., drive train rebuild) as well as the cost of any additional planned mid-life overhaul activities (if any). These costs are oriented toward the larger component replacement, rebuild, or rehabilitation needs and exclude the cost of minor vehicle repairs. Examples include:
  - Engine and transmission rebuilds
  - Other expected component replacements (e.g., brakes, tires, batteries, suspension)
  - Mid-life overhaul costs (e.g., repainting; replacement of flooring, upholstery, windows; bodywork)
- **Operating and Maintenance Costs**: Includes the cost of fuel, preventative maintenance programs, and the cost of all labor and parts for minor repairs as required to maintain vehicles in good working order.

The following sub-sections provide an analysis of the expected annual cost of these different cost types throughout the vehicle life cycle, beginning with a discussion of expected component replacement and mid-life overhaul costs.

Expected Component Replacement and Overhaul Costs

Figure E-1 presents the distribution of expected major component replacement and overhaul costs over a potential 20-year life cycle for a 40-foot transit bus (hence, it excludes the cost of vehicle acquisition and all other vehicle operating and maintenance costs). The chart assumes a vehicle that averages 35,000 miles per year over the full life cycle. The chart also considers the two cases of: (1) those agencies that complete an extensive mid-life overhaul and (2) those agencies that do not complete a mid-life rebuild but carry out their major component replacements on a continuous, as-needed basis. The analysis also assumes that the number of times a given replacement/rebuild activity is performed depends on the vehicle's age at the time of retirement. For example, if engine rebuilds occur on roughly a six-year cycle (every 210,000 miles), then this activity will occur once for a vehicle retired before 12 years, twice for a vehicle retired before 18 years, and 3 times for a vehicle retired at age 20 or later. Similarly, it is assumed that agencies currently pursuing a major mid-life rebuild program at vehicle age 7 (for example) would want to repeat the process again at age 14 if the vehicle was expected to operate well past that age.

Figure E-1



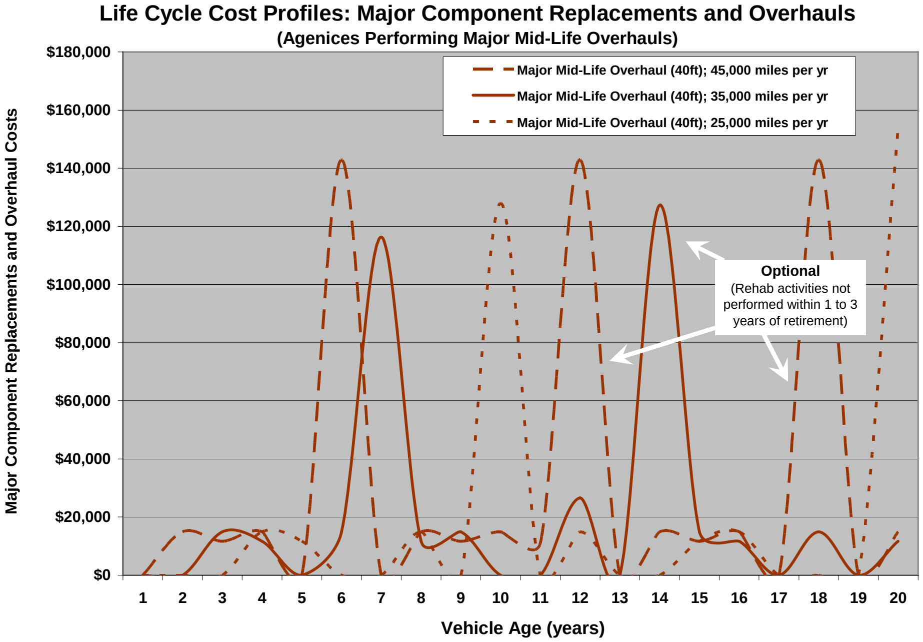
In reviewing Figure E-1, it is easy to identify the timing of major vehicle replacement activities. In particular, the timing of the seven-year major mid-life overhaul (and its potential repetition at age 14) stands out clearly. These investments include the cost of engine and transmission rebuilds, repainting, significant rehab and replacement of vehicle interiors (flooring, upholstery, and windows), bodywork as needed, some electrical work, and other upgrades. In contrast, the mid-life peaks for those agencies that do not perform a major mid-life overhaul are significantly lower (fewer rehab activities equate to lower costs) but also have higher cost peaks for the intervening years (as some replacement activities tend to be more spread out). The smaller peaks primarily represent replacement of those components having shorter expected lives including tires, brakes, and batteries.

From the viewpoint of evaluating FTA's service-life policy, the key point is that, whether or not an agency conducts a major mid-life overhaul, there are major cost cycles that are repeated throughout an vehicle's life cycle, which are roughly concurrent with drive-train rebuilds (e.g., the cost peaks at roughly ages 6 to 7 and 12 to 14 in Figure E-1). These major cycles help guide agency rehab-replacement decisions—specifically, agencies will only complete a major vehicle rehabilitation initiative if they intend to keep that vehicle in service for at least three to five years after these improvements have been made. For example, in the case of a heavy-duty vehicle approaching 12 years in age, an agency will only reinvest in that vehicle (e.g., rebuild/replace the engine and transmission) if the agency intends to obtain an additional three to five years of revenue service from that vehicle. Otherwise, these rehabilitation activities will be avoided (to save cost) and the vehicle will be retired *after* the minimum retirement requirements have been satisfied. To summarize, vehicle rehab and replacement decisions are determined by the timing of the vehicle's major reinvestment cycles, with the timing of these cycles determined by annual vehicle mileage, average operating speed and environment, and agency maintenance practices.

Finally, the difference in the timing of the "mid-life" activities, as presented in Figure E-1, is an artifact of the particular operating characteristics, maintenance practices, and service performance standards of the sample of agencies that provided data for this study. In other words, it should not be expected that all major mid-life overhauls only occur at age seven (they may happen earlier or later depending on differences in average annual mileage, rehab policies, funding availability, and other factors). Similarly, those agencies that perform more continuous rehabs do not all concentrate their "mid-life" activities at age six. Rather, these activities are "spread out" over multiple years. Again, the exact timing of these activities can and do occur at differing times for different agencies depending on differences in annual mileages, rehabilitation practices, and operator finances.

Figure E-2 highlights how differences in annual vehicle mileages can impact the timing and cost of component replacement and overhaul activities. Specifically, this example presents the expected life-cycle cost profile for agencies performing major mid-life rebuilds but with fleet vehicles traveling an average of 45,000; 35,000; or 25,000 miles per year. As expected, vehicles traveling fewer miles per year require less frequent component replacements (and hence lower average annual costs), while higher mileage vehicles have more frequent component replacement needs. This same analysis is repeated for those agencies that do not perform major mid-life rehabs in **Figure E-3**.

Figure E-2



Annualized Acquisition, Major Component Replacement, and Overhaul Costs

The analysis next adds the cost of vehicle acquisition to the component and mid-life rehabilitation costs considered above (operating and maintenance costs are considered shortly). All of these costs are then annualized over different time periods. The combined, annualized costs are presented in **Figure E-4**. The cost values in this chart provide a measure of the average cost of ownership for a 40-foot vehicle at each vehicle age.[15] As the number of years of ownership increase, the vehicle's acquisition cost is spread over an increasing number of years, thus reducing the average annualized cost of ownership (leading to the downward sloping curve). The bumps in this curve capture the timing of major component replacement and overhaul activities (costs that also decrease on an annualized basis as vehicle age increases as these costs are spread over increasing years of service).

---

[15] *More precisely, annualized cost is not the actual cost divided by the number of years of service (e.g., acquisition cost / vehicle age). Rather, annualized cost represents the stream of annual payments the net present value of which are equivalent to the initial investment cost. Specifically, the annualized cost of the vehicle acquisition cost for any age is given by* $\left(Acquisition\ Cost\right) * \left(i / \left(1 - (1+i)^{-(Vehicle\ Age)}\right)\right)$.

Figure E-3

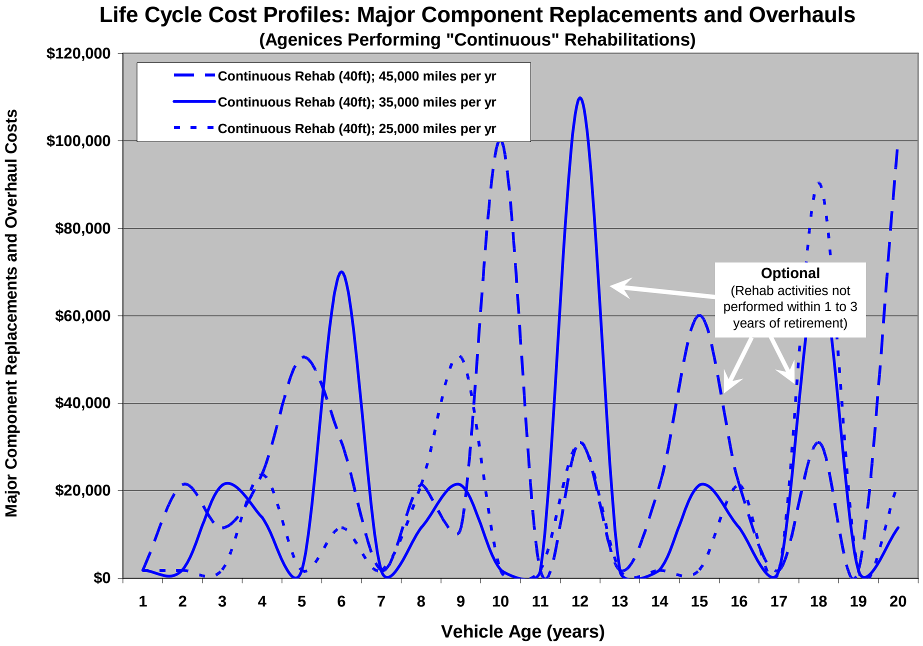


Figure E-4

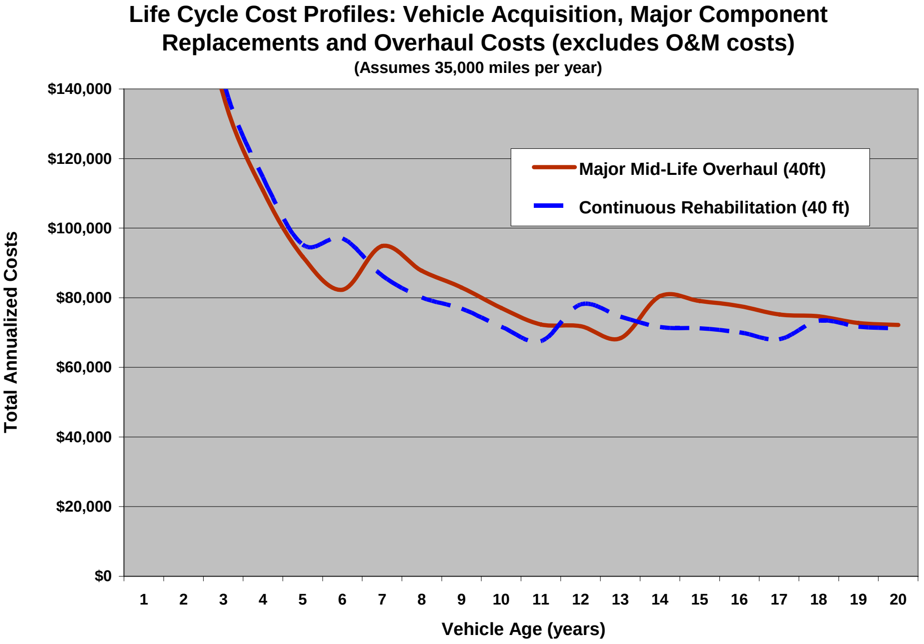


Figure E-5 reproduces the analysis in Figure E-4 for those agencies that do pursue comprehensive mid-life overhauls, but this time for the three annual mileage groupings including 45,000, 35,000, or 25,000 miles. **Figure E-6** does the same for agencies that perform vehicle rehabilitation on a more continuous basis. Both of these charts capture the increase in annualized cost as annual vehicle miles increase, the higher annualized costs for those agencies pursuing extensive mid-life overhauls, and the overall flattening of the annualized cost curves as the number of years of service approaches and surpasses 12 years.

Figure E-5

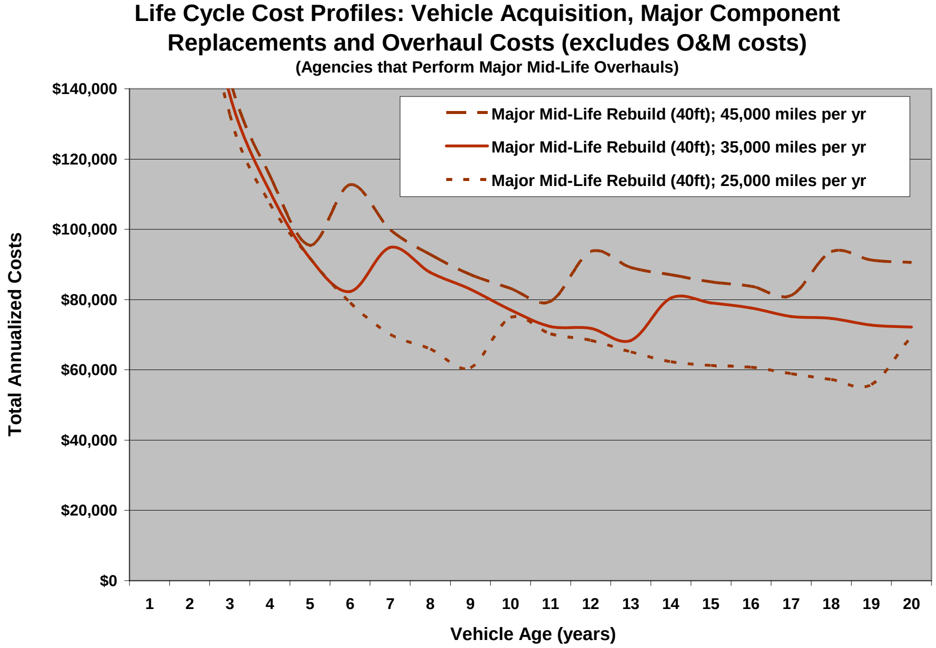
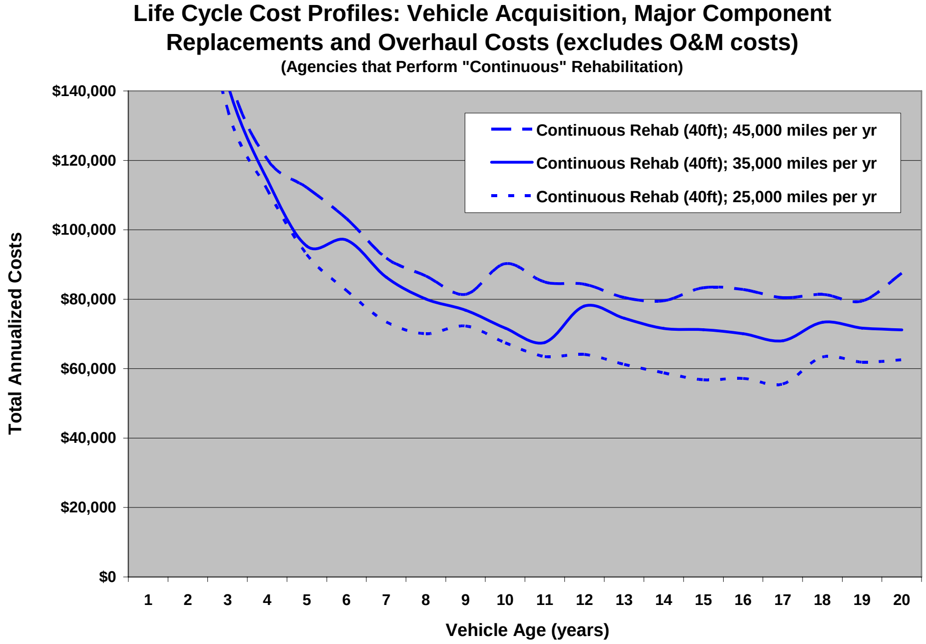


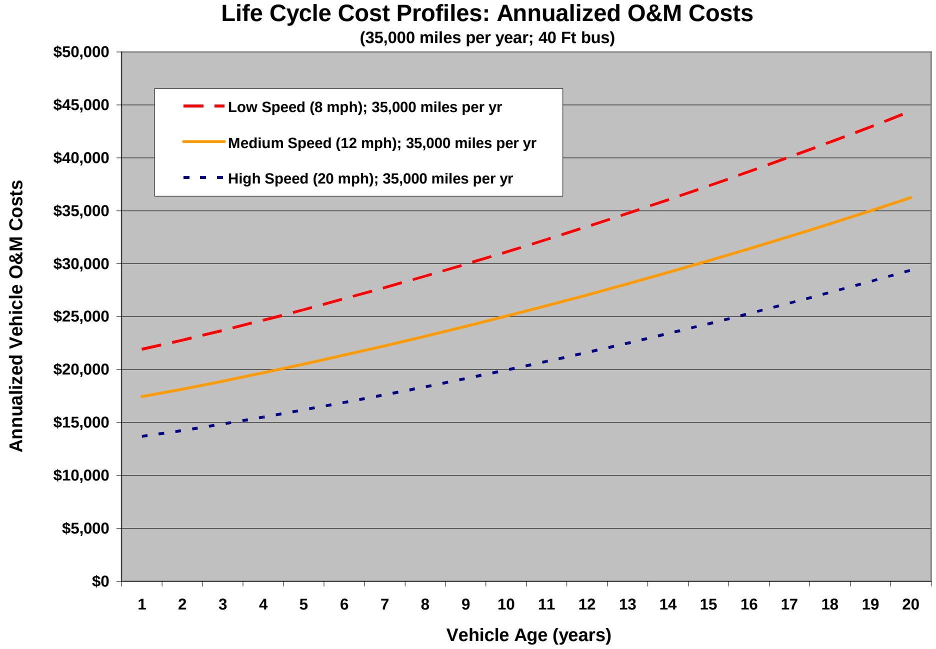
Figure E-6



Annualized Operating and Maintenance Costs

The analysis above considers all life-cycle costs excluding basic operating and maintenance (O&M) costs (i.e., the cost of fuel, and corrective and preventive maintenance). As described above, vehicle O&M costs tend to increase as the total number of vehicle miles increase. O&M costs also tend to be higher for fleets operating in more congested urban areas, and hence experiencing heavy-duty cycles. **Figure E-7** presents estimates of changes in annual vehicle operating and maintenance costs based on data obtained from a sample of bus operators throughout the State of Illinois.

Figure E-7



Total Annualized Life-Cycle Costs

Finally, this section combines all of the prior annualized costs—including the costs of vehicle acquisition, major component replacement, major overhaul (if any), and operations and maintenance (O&M) costs—into a single annualized cost measure. The analysis then considers the annualized vehicle costs and minimum cost replacement points for the following combinations of operator characteristics:

- Performance of major mid-life overhaul: yes or no
- Differing annual average mileages: 25,000; 35,000; and 45,000 miles per year
- Number of overhauls (for agencies performing major mid-life overhauls) or drive train rebuilds (for agencies performing continuous rehabilitation) over the life of the vehicle including: No overhaul (or drive train rebuild), one overhaul (or drive train rebuild), and multiple overhauls (or drive train rebuilds)

This represents a total of 18 different scenarios for analysis.

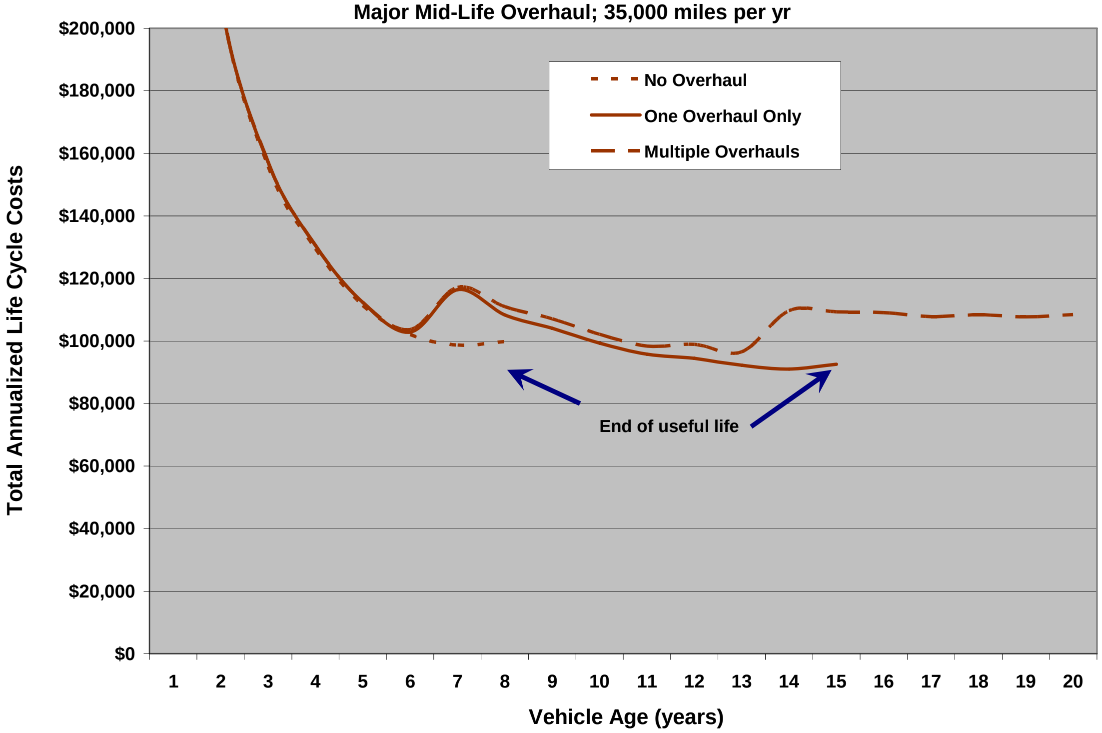
Agencies Performing Major Mid-Life Overhauls

Figure E-8 presents the total life-cycle cost profile (including annualized acquisition, component replacement, vehicle overhaul, and O&M costs) for an agency that: (1) performs a major mid-life overhaul and (2) operates its fleet vehicles an average of 35,000 miles per year (roughly the national average). The three lines in the chart consider the differing options of: (1) performing no mid-life overhaul (including no mid-life drive train rebuild), (2) performing one mid-life overhaul (the standard), and (3) performing two "mid-life" overhauls (the second to extend vehicle life toward 20 years).

Figure E-8

Total Life Cycle Cost Profiles

Major Mid-Life Overhaul; 35,000 miles per yr



Note that the cost curve for the "no overhaul" scenario has been cut off at age 8, while the curve for the "one overhaul only" curve has been cut off at vehicle age 15. These cut-off points reflect the assumption that agencies not performing an engine and transmission rebuild at approximately age six or seven cannot expect the vehicle to remain in reliable working order more than a few years (e.g., age eight). Similarly, if the agency completed a major rebuild at age 7, an additional major rebuild will be required to maintain service quality beyond age 14 or 15. The results in Figure E-8 suggest that total annualized life-cycle costs are: (1) minimized at different vehicle ages for the three major overhaul options (none, one, or two) and (2) are lowest for the one-overhaul option and highest for the two-overhaul option. **Table E-1** presents the cost minimum amounts and ages for these three alternatives.

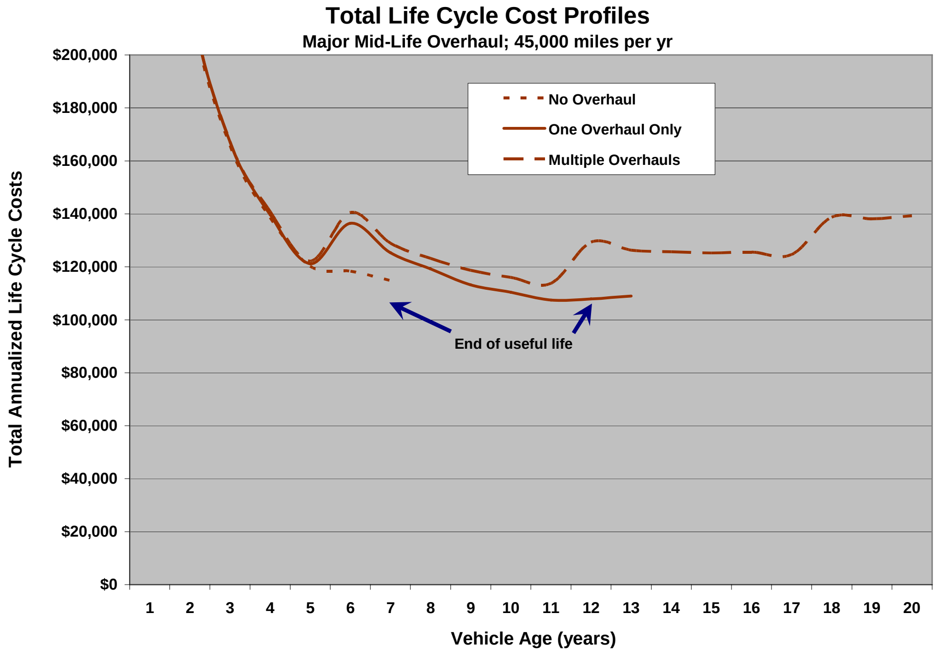
Table E-1
Life-Cycle Cost Minimums: Major Mid-Life Overhauls – 35,000 Annual Miles

Number of Overhauls	Annualized Life-Cycle Cost Minimum ($2006)	Vehicle Age at Cost Minimum (years)
No Overhaul	$99,000	Between 7 to 8
One Overhaul	$91,000	Between 14 to 15
Multiple Overhauls*	$96,000	13

* This option does not make logical sense as the minimum cost point is reached before the second major rehabilitation

Both the chart and table indicate that the one-overhaul option is the optimal choice from a cost perspective and that this minimum cost point is reached at roughly age 14 to 15, or two to three years after the current FTA service-life minimum for this "12-year" vehicle type. In contrast, the multiple-overhaul option is not cost effective relative to either the no- or one-overhaul options (as its cost minimum is both *higher* and *earlier* than the one-overhaul alternative and *prior* to the second overhaul). Overall, the annualized cost differences between each option are clear but not significantly different (i.e., the most expansive, no-overhaul option is roughly 10 percent more than the least expensive, one-overhaul option).

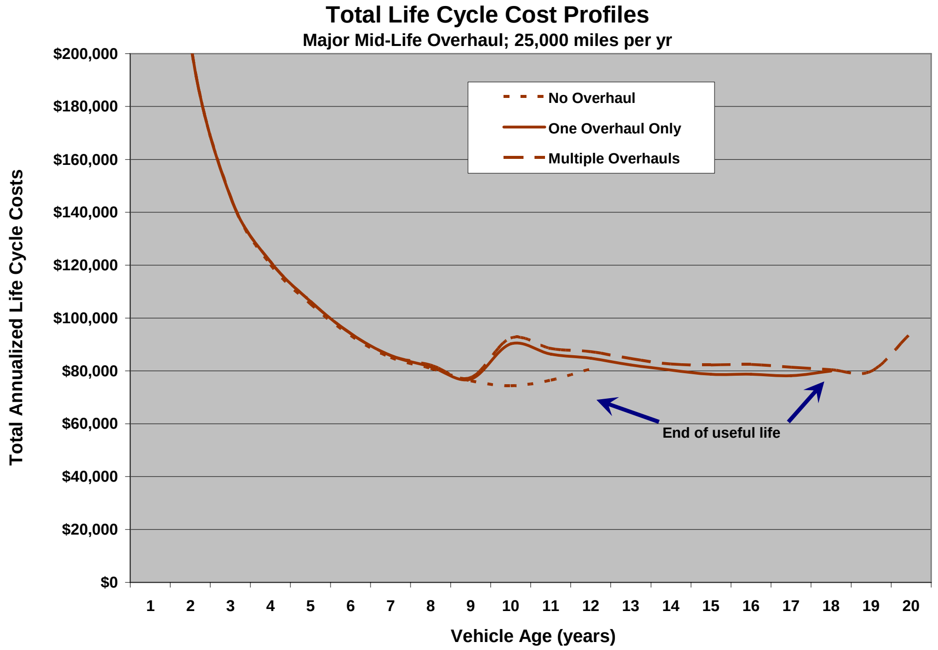
Figure E-9



The analysis above suggests that life cycle costs for a 40-foot vehicle averaging roughly 35,000 miles per year and receiving a major mid-life overhaul occurs roughly around age 14 or 15, or two to three years after the current FTA minimum of 12 years. Note here that 35,000 annual miles is roughly the national average for this vehicle type.

For vehicles with lower or high average annual mileages, **Figure E-9** considers the life-cycle cost profiles for the 45,000 annual mile scenario, and **Figure E-10** for the 25,000 annual mile scenario.

Figure E-10



High Annual Mileage (45,000 per year): Figure E-9 considers the case of an agency that does perform an extensive mid-life overhaul with fleet vehicles traveling an average of 45,000 miles per year. In this case, the one-overhaul option is clearly the most cost effective (**Table E-2**). In this case, the cost minimum is reached somewhere between 11 and 12 years of vehicle life and close to 500,000 miles. In contrast, neither the multiple major overhaul nor the no-overhaul options appear while the no-overhaul option being (marginally) the most expensive.

Table E-2
Life-Cycle Cost Minimums: Major Mid-Life Overhauls – 45,000 Annual Miles

Number of Overhauls	Annualized Life-Cycle Cost Minimum ($2006)	Vehicle Age at Cost Minimum (years)
No Overhaul	$115,000	7
One Overhaul	$108,000	Between 11 and 12
Multiple Overhauls	$114,000	Between 10 and 11

Low Annual Mileage (25,000 per year): Figure E-10 considers an agency that does perform an extensive mid-life overhaul but with fleet vehicles traveling an average of 25,000 miles per year. In this case, the no-overhaul option is the most cost effective (**Table E-3**), but only marginally more so as compared to the one-overhaul option.

Table E-3
Life-Cycle Cost Minimums: Major Mid-Life Overhauls; 25,000 Annual Miles

Number of Overhauls	Annualized Life-Cycle Cost Minimum ($2006)	Vehicle Age at Cost Minimum
No Overhaul	$74,000	10
One Overhaul	$78,000	17
Multiple Overhauls	$79,000	19

As will be shown later when considering those agencies that do not perform a major-mid-life overhaul (i.e., those that perform continuous rehabilitations), agencies with lower annual mileage per fleet vehicle may be better off performing less than the full overhaul and retiring their 12-year fleet vehicles some time after ages 14 or 15. (Note here that this and all other scenarios were evaluated based on the data obtained for this study. In reality, it is not certain that there are any agencies with low annual miles per vehicle that actually perform a full life-extending overhaul).

Summary: Agencies Performing Major Mid-Life Overhauls

In summary, for those agencies that do perform major life-extending rehabilitations, the one-overhaul option appears to be the most cost effective for most operators (i.e., those with average or higher annual mileage). From a cost-effective perspective, those with lower mileage (i.e., less than or equal to 25,000 miles annually) are likely best off performing a scaled-down rehabilitation around age 9 and then operating the vehicle past age 14 (this scenario will be considered in greater depth in the following section under the “continuous” rehabilitation agency discussion). The multiple-overhaul option was not found to be cost effective within the scenarios considered here (in all cases, this option experiences its cost minimum before a second rehabilitation is undertaken). Finally, while the one-overhaul option generally appears to be the most cost effective, the total life-cycle cost difference between this and the no-overhaul option (on an annualized basis) was not found to be more than 10 percent.

Implications for Useful Life: Agencies Performing Major Mid-Life Overhauls

When evaluated solely in terms of cost-effectiveness, vehicles with average mileages of between 35,000 and 45,000 miles per year reach their minimum annualized life-cycle cost after the FTA’s current 12-year minimum retirement age (i.e., 14 years for vehicles with 35,000 annual miles and 12 years for vehicles with 45,000 annual miles). Assuming agencies with lower mileages choose to avoid the more-extensive mid-life rehabilitation in favor of the less-expensive continuous rehabilitation (as discussed below), these agencies reach their minimum annualized life-cycle cost between ages 14 and 16 (depending on the rehabilitation activities completed).

Agencies Practicing Continuous Rehabilitation

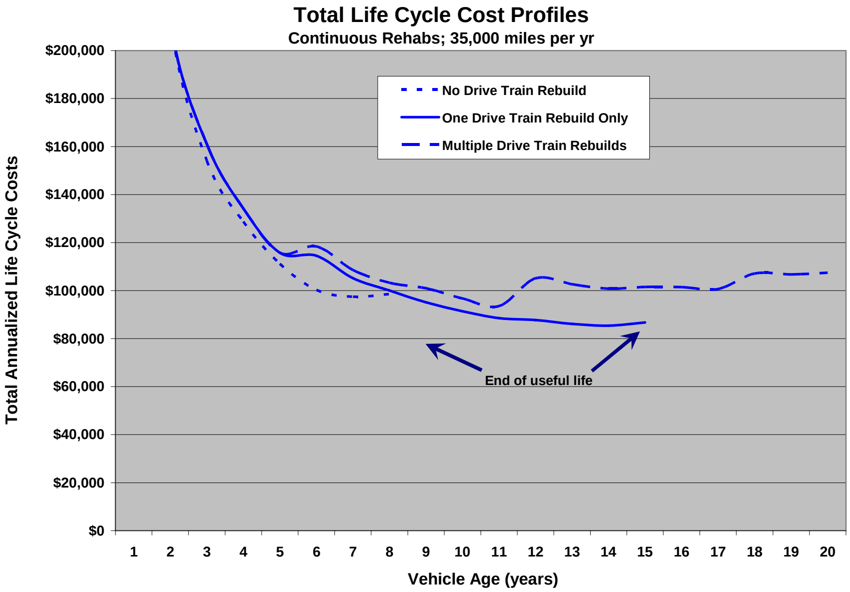
The preceding analysis considered those agencies that undertake major life-extending overhauls some time near the mid-point of a vehicle’s expected useful life (examples include New York City Transit, New Jersey Transit, and WMATA). These agencies are characterized by above-average duty cycles, high ridership, and highly congested urban environments—factors that require more significant rehabilitation activities to ensure reliable operability and quality of service over the vehicle’s life. In contrast, most U.S. transit operators (in particular, the smaller and mid-size operators) do not perform a single, major mid-life overhaul. Rather, these agencies complete rehabilitation activities on an as-needed or continuous basis. Moreover, these agencies will ultimately perform many, if not most, of the same rehabilitation activities as those agencies that do complete a major overhaul, but not in a single, coordinated event. In other words, these operators tend to spread their rehabilitation activities throughout the vehicle’s life cycle.

Rehabilitation Assumptions: Once again, agencies performing continuous vehicle rehabilitation complete many of the same rehabilitation activities as those conducting a full mid-life overhaul. The following are key examples of rehabilitation activities not typically performed by continuous rehabilitation operators: chassis or structural element refurbishment or reconstruction (not related to a significant accident), major body work, complete refurbishment of vehicle interior, replacement of fare collection equipment, interior climate control replacement, and electrical system upgrades.[16]

Similar to the analysis above, this analysis of the continuous rehabilitation operators does assume that operators make a determination of how many major rehabilitation cycles their vehicles undergo throughout the vehicle's life cycle. Specifically, the analysis considers the options of: (1) one drive train rebuild, (2) multiple drive train rebuilds, or (3) no drive train rebuild. Despite its name, the "no drive train rebuild" scenario considered here *does* assume one transmission rebuild three or four years into the vehicle life cycle. However, this is the only drive train rehabilitation activity assumed under the "no drive train rebuild" scenario.

Average Annual Mileage (35,000 per year): Figure E-11 presents the total life-cycle cost profile (including annualized acquisition, component replacement, vehicle overhaul, and O&M costs) for an agency that: (1) performs continuous vehicle rehabilitation and (2) operates its fleet vehicles an average of 35,000 miles per year (roughly the national average).

Figure E-11



---

[16] *In practice, the complete list of rehabilitation activities performed over a vehicle's life cycle can vary significantly across agencies. Hence, some "continuous rehab agencies" may perform one or more of the rehabilitation activities excluded from this analysis of this agency "type." Moreover, continuous rehab agencies will sometimes need to perform some of these activities on a periodic basis due to extenuating circumstances (e.g., problem vehicles/components or accident repairs). The intention here is to group operators into two basic types: those that do and those that do not perform major mid-life overhauls. In reality, there is a range of rehabilitation practices, each particular to the specific needs, objectives, and management practices of the nation's many bus operators.*

Table E-4 shows that, in this case, the one-drive-train rebuild option is clearly the most cost effective. Similar to the above, the multiple-drive-train rebuild scenario experiences its cost minimum prior to the second rebuild event, thus negating any logic to multiple rebuilds. In contrast, the no-drive-train rebuild scenario does not provide sufficient time to distribute vehicle acquisition costs over sufficient years to compete with the one-rebuild option. This option is roughly 15 percent more costly as compared to the one-drive-train rebuild option.

Table E-4
Life-Cycle Cost Minimums: Continuous Rehabilitation – 35,000 Annual Miles

Number of Overhauls	Annualized Life-Cycle Cost Minimum ($2006)	Vehicle Age at Cost Minimum
No Drive Train Rebuild	$97,000	7
One Drive Train Rebuild	$85,000	14
Multiple Drive Train Rebuilds	$94,000	11

High Annual Mileage (45,000 per year): Figure E-12 considers the case of an agency performing continuous rehabilitations with fleet vehicles traveling an average of 45,000 miles per year. Here again, the one-drive-train rebuild option is easily the most cost effective, occurring at roughly age 14. This option is roughly 15 percent more cost effective as compared to the no-drive-train rebuild option.

Table E-5 summarizes the life-cycle cost analysis and the results of the minimum-cost values for each of the high-mileage scenarios presented in Figure E-12. For this higher-mileage scenario, the one-rebuild option is necessary to reach the 12-year life and provides the lowest minimum life-cycle cost.

Figure E-12

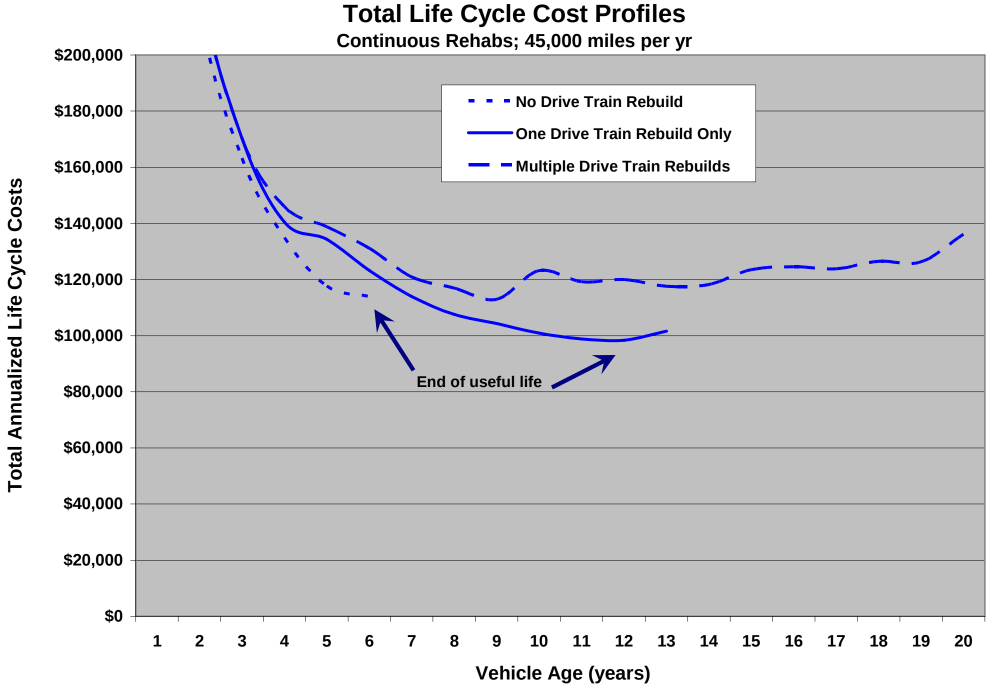


Table E-5
Life-Cycle Cost Minimums: Continuous Rehabilitation – 45,000 Annual Miles

Number of Overhauls	Annualized Life-Cycle Cost Minimum ($2006)	Vehicle Age at Cost Minimum
No Drive Train Rebuild	$114,000	6
One Drive Train Rebuild	$98,000	12
Multiple Drive Train Rebuilds	$113,000	9

Low Annual Mileage (25,000 per year): Figure E-13 considers the case of an agency performing continuous rehabilitation with fleet vehicles traveling an average of 25,000 miles per year. In this case, the one-drive train rebuild option is marginally more cost effective as compared to the no-rebuild option. Once again, the multiple-rebuild option makes little sense, with the cost minimum attained just prior to the second engine rebuild event.

Table E-6 summarizes the life-cycle cost analysis and the results of the minimum-cost values for each of the high-mileage scenarios presented in Figure E-13. For this higher-mileage scenario, the one-rebuild option is necessary to reach the 12-year life and also provides the lowest minimum life-cycle cost.

Figure E-13

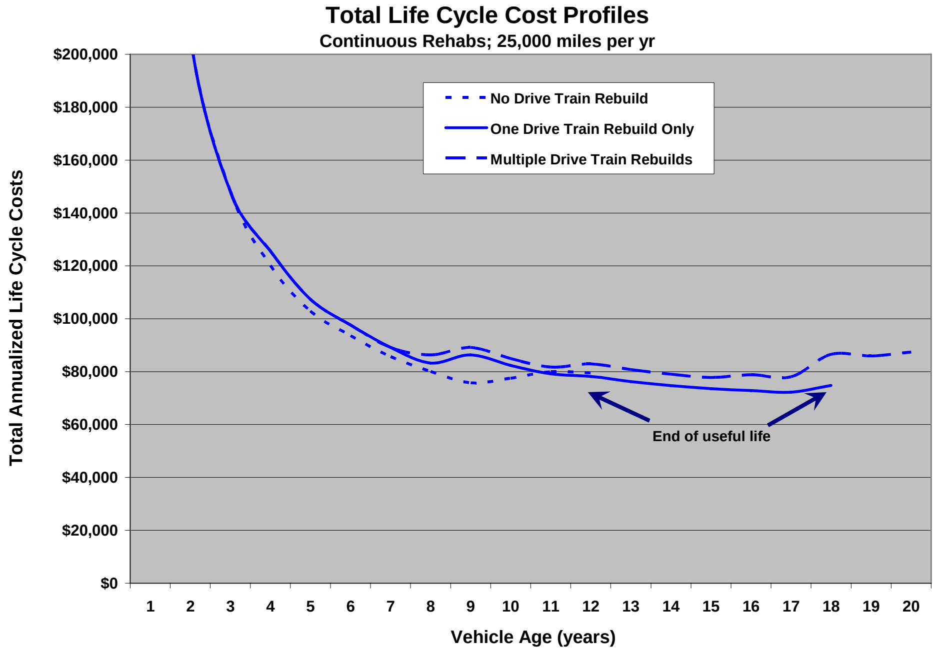


Table E-6
Life-Cycle Cost Minimums: Continuous Rehabilitation – 25,000 Annual Miles

Number of Overhauls	Annualized Life-Cycle Cost Minimum ($2006)	Vehicle Age at Cost Minimum
No Drive Train Rebuild	$76,000	9
One Drive Train Rebuild	$72,000	17
Multiple Drive Train Rebuilds	$78,000	17

Summary: Agencies Performing Continuous Vehicle Rehabilitation

In summary, for those agencies that do perform vehicle rehabilitations on a continuous, as-needed basis, the one-overhaul option appears to be the most cost effective for operators high, average, and low annual mileages (with the advantage being only marginal for lower mileage operators). The multiple-overhaul option was not found to be cost effective within the scenarios considered here (in all cases, this option experiences its cost minimum *before* a second rebuild is undertaken). Finally, the one-drive-train rebuild option was found to have roughly a 15-percent cost advantage over the other options for operators with 35,000 or more in annual mileage. This advantage was only a little more than 5 percent for agencies with 25,000 in annual mileage.

Implications for Useful Life: Agencies Performing Continuous Rehabilitation

When evaluated solely in terms of cost-effectiveness, vehicles with average annual mileages of 25,000; 35,000; and 45,000 miles per year reach their minimum annualized life-cycle cost on or after FTA’s current 12-year minimum retirement age (i.e., 17 years for vehicles with 25,000 annual miles, 14 years for vehicles with 35,000 annual miles, and 12 years for vehicles with 45,000 annual miles).

Summary: Minimum Life-Cycle Cost Values and Ages

Tables E-7 and E-8 respectively identify the minimum annualized life cycle cost values and the ages at which these cost minimums are attained (by annual vehicle mileage). Each table highlights the cost minimum values and ages for each annual mileage group.

Table E-7
Minimum Life-Cycle Cost Values ($2006)*

Annual Vehicle Mileage	Agency Performs: Major Mid-Life Overhauls			Agency Performs: Continuous Vehicle Rehabilitation		
	No Overhaul	One Overhaul	Multiple Overhauls	No Drive Train Replacement	One Drive Train Replacement	Multiple Drive Train Replacements
25,000	$74,000	$78,000	$79,000	$76,000	$72,000	$78,000
35,000	$99,000	$91,000	$96,000	$97,000	$85,000	$94,000
45,000	$115,000	$108,000	$114,000	$114,000	$98,000	$113,000

* Note: Differences in costs between agencies that do and do not perform major mid-life overhauls reflect both: (1) differences in rehabilitation activities performed and (2) differences in the cost data provided by those agencies participating in this study.

With one exception, minimum life-cycle cost is attained at or after the current FTA 12-year minimum. The exception is those agencies with 25,000 average annual miles that ordinarily perform a major life-extending rehabilitation. (As noted above, it is unlikely that agencies would pursue this option as, with only 25,000 miles per year, it is likely more cost-effective to perform a less extensive rehabilitation around year 10 and then operate the vehicle until age 14 or later).

Table E-8
Minimum Life-Cycle Cost Ages

Annual Vehicle Mileage	Agency Performs: Major Mid-Life Overhauls			Agency Performs: Continuous Vehicle Rehabilitation		
	No Overhaul	One Overhaul	Multiple Overhauls	No Drive Train Replacement	One Drive Train Replacement	Multiple Drive Train Replacements
25,000	10	17	19	9	17	17
35,000	9	14	13	7	14	11
45,000	7	12	11	6	12	9

Higher-Mileage Vehicles

The vehicles with 45,000 miles experience their cost minimum at 12 years. When converted to miles, this equates to 540,000 miles (12 X 45,000) by the age of retirement. Here again, the life-cycle cost analysis results are in line with the current FTA minimum life requirements of 12 years *or* 500,000 miles. Hence, although the age at which the minimum life-cycle cost value is attained continues to decline as average annual mileage increases, these operators can take advantage of FTA's current minimum 12-year ***or*** 500,000-mile-of-service option to ensure retirement at the minimum life-cycle cost point. Hence, based on this cost-effectiveness assessment, the current minimum-life mileage requirement of 500,000 appears reasonable.

Generalized Analysis

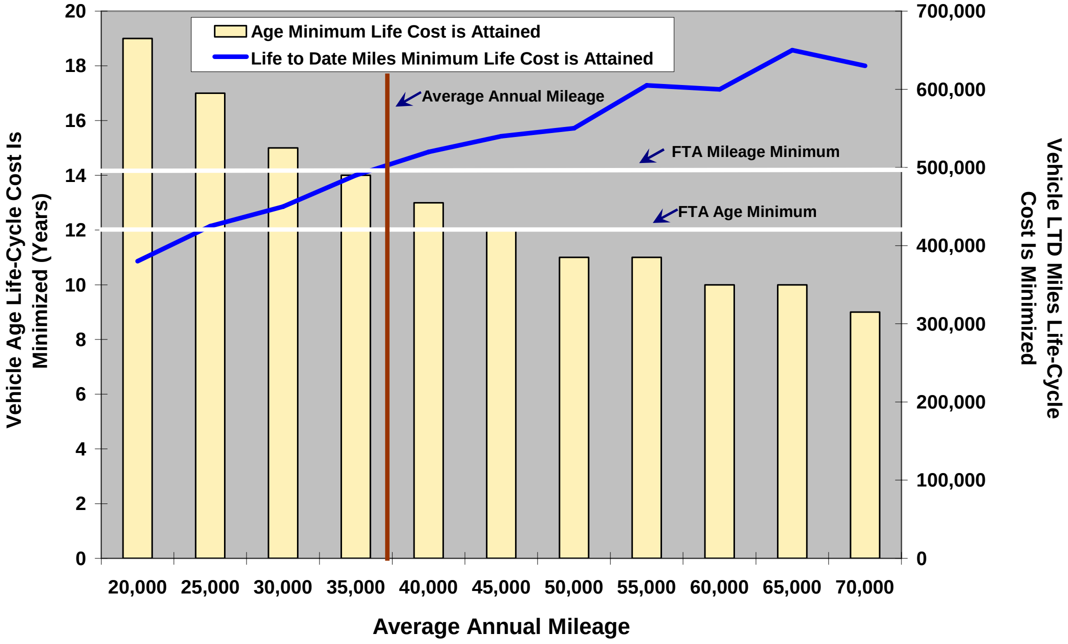
The analysis above considered the minimum life-cycle cost for three specific annual vehicle mileages: 25,000; 35,000 (the national average); and 45,000. **Figure E-14** provides the ages and LTD mileages at which life-cycle costs are minimized for vehicles traveling between 20,000 miles and 70,000 miles annually. Here, the solid bars and left-side axis present the ages at which life-cycle costs are minimized for this range of annual vehicle mileages. The solid line and right-hand axis present the LTD mileages at which life-cycle costs are minimized.

Review of E-14 suggests that, from a cost-effective perspective, FTA's current retirement minimums (for large buses) of 12 years or 500,000 miles represent reasonable choices. For ***all*** annual vehicle mileages, the minimum cost point is attained at either an age or mileage that exceeds one or both of the FTA minimums for these measures. In all cases, the difference between one and both of the current FTA minimum requirements also provides some margin for the early retirement of vehicles with reliability problems. For example, vehicles traveling an average of 40,000 miles per year could reach their cost minimums at age 13 and an LTD mileage of 520,000 miles. Hence, this provides a "margin" of one year or 20,000 miles of optimal service beyond the FTA minimum for an average vehicle or the option to reduce service life by these amounts for less reliable vehicles. Moreover, this difference between the 12-year and 500,000-mile minimum is smallest (while still providing a meaningful early retirement margin) for vehicles that average between 30,000 and 45,000 miles of travel per year. Together, these vehicles account for more than 70 percent of the nation's large buses.

Figure E-14

Age and Mileage at Which Life-Cycle Cost Is Minimized

(Single Mid-Life Rehabilitation or Single Drive Train Replacement)



APPENDIX F. AGENCY SUPPLIED LIFE-CYCLE COST DATA

The following are the contents of the life-cycle cost database created for this study using data supplied by the local transit operators and vehicle manufacturers responding to the study interview guide. This information includes the expected cost and timing (in years) for replacement of all major vehicle components. The cost data have been “pooled” and averaged here to provide a more complete and representative set of vehicle life-cycle costs. Given this pooling, the tables below present cost data for three different “operator” types:

- Large operators that perform a major mid-life rehabilitations
- Operators that do not perform mid-life overhauls
- Vehicle manufacturers supplying life-cycle cost data.

In the end, the life-cycle cost data supplied by the vehicle manufacturers was not used for this study as it was found to differ significantly from the actual cost experiences of the nation’s transit operators. Also, the cost data supplied by agencies (including those that do and do not perform major rehab activities) is representative of agencies with average annual mileages of roughly 37,500 annual miles (for those do perform major mid-life rehabilitations) and roughly 36,000 miles (those than do not major mid-life rehabilitations). These cost data were then adjusted accordingly for the analyses presented in Chapter 6.

Table F-1
Large Operator: With Major Rehab

Comp ID	Group	Component	Replacement Cost	Expected Life (years)
1	Body	Structure		14
2	Body	Exterior and Applied Panels		
3	Body	Paint	$2,500.00	7
4	Body	Interior		
5	Body	Floor	$2,200.00	7
6	Body	Steps and Stepwells	$120.00	7
7	Body	Wheel Housings	$1,720.00	7
8	Body	Exit Passenger Doors	$3,000.00	7
9	Body	Service Compartment		
10	Body	Engine door Access Doors		
11	Operating Components	Doors	$38.00	7
12	Operating Components	Windshield Wipers and Washers	$190.00	3
13	Operating Components	Headlight Assy Lighting		
14	Operating Components	Dimmer switch Controls		
15	Operating Components	Speedometer Instruments		
16	Interior	Trim Panels		
17	Interior	Headlining		

Comp ID	Group	Component	Replacement Cost	Expected Life (years)
18	Interior	Front End		
19	Interior	Rear End		
20	Interior	Passenger Info and Advertising		
21	Interior	One Seat Insert Passenger Seats	$3,400.00	7
22	Interior	Driver's Seat	$1,356.00	3
23	Interior	Rubber Floor Covering		
24	Windows	Windshield	$2,500.00	14
25	Windows	Driver's Side Window	$500.00	14
26	Windows	Side Windows	$3,000.00	14
27	Insulation	Insulation		
28	Ancillary Items	Dash Panels		
29	Ancillary Items	Visors		
30	Ancillary Items	Chime Exit Signal		
31	Ancillary Items	Outside Mirrors	$760.00	3
32	Ancillary Items	Inside Mirrors		
33	Passenger Assists	Front Doorway		
34	Passenger Assists	Vestibule		
35	Passenger Assists	Overhead		
36	Passenger Assists	One Set Insert Longitudinal Seats		
37	Passenger Assists	Rear Doorway		
38	Bumpers	Front Bumper	$1,893.00	7
39	Bumpers	Rear Bumper	$923.00	7
40	Destination Signs	Run Box Run Numbers	$6,545.00	7
41	Destination Signs	Rear Route # Route Numbers		
42	Destination Signs	Front Main Auxiliary Destination Sign		
43	Destination Signs	Fare Collection Device		
44	Destination Signs	Wheelchair Lift	$12,000.00	7
45	Destination Signs	Wheelchair Restraints		
46	ITS Components	AVL		
47	ITS Components	APC		
48	ITS Components	Others		
49	Propulsion System	Engine Mounts	$500.00	7
50	Propulsion System	Accessories	$2,000.00	7
51	Propulsion System	Pump Hydraulic Drive	$1,200.00	7
52	Propulsion System	Engine	$12,940.00	7
53	Propulsion System	Radiator Cooling System	$3,700.00	3
54	Propulsion System	Transmission	$11,643.00	4
55	Propulsion System	Muffler Cat Conv Exhaust System	$4,300.00	7
56	Propulsion System	EGR Emissions Control Devices	$1,900.00	7
57	Propulsion System	Reman Diff Axles and Differential	$9,000.00	7
58	Propulsion System	Sway Bar Suspension		
59	Propulsion System	Air Springs		
60	Propulsion System	Shock Absorbers		

Comp ID	Group	Component	Replacement Cost	Expected Life (years)
61	Propulsion System	Steering Gear		
62	Propulsion System	Steering		
63	Brakes	Brake Chamber Actuators		
64	Brakes	Rear Axel Set Friction Material		
65	Brakes	Hubs	$2,800.00	7
66	Brakes	One Drums or Rotors		
67	Brakes	Compressor Air System	$3,500.00	3
68	Brakes	Wheels		
69	Brakes	Tires	$1,600.00	3
70	Fuel System	Fuel Tank		
71	Fuel System	Fuel Filler		
72	Electrical Components	Batteries		
73	Electrical Components	Master Battery Switch		
74	Electrical Components	Fire Detectors		
75	Electrical Components	Radio Noise Suppression		
76	Interior Climate Control	Master control a/c heat Controls		
77	Interior Climate Control	Plenums and Vents		
78	Interior Climate Control	Filter Air Intakes		
79	Interior Climate Control	Radio & Public Address System	$8,000.00	7
99	Body/Structure	Other Overhaul Costs	$7,000.00	7
99	Body/Body	Other Overhaul Costs	$3,000.00	7
99	Interior	Other Overhaul Costs	$8,244.00	7
99	Fare Collection	Other Overhaul Costs	$5,000.00	14
99	Suspension	Other Overhaul Costs	$4,600.00	7
99	Brakes	Other Overhaul Costs	$5,000.00	7
99	Fuel System	Other Overhaul Costs	$1,500.00	7
99	Electrical Components	Other Overhaul Costs	$3,810.00	3
99	Interior Climate Control	Other Overhaul Costs	$10,000.00	7

Table F-2
Mid to Large Operator: No Major Rehab

Comp ID	Group	Component	Replacement Cost	Expected Life (years)
1	Body	Structure		12
2	Body	Exterior and Applied Panels	$180.26	12
3	Body	Paint	$3,000.00	6
4	Body	Interior		12
5	Body	Floor		12
6	Body	Steps and Stepwells		12
7	Body	Wheel Housings		12
8	Body	Exit Passenger Doors	$1,742.44	6
9	Body	Service Compartment		12
10	Body	Engine door Access Doors	$2,350.71	6

Comp ID	Group	Component	Replacement Cost	Expected Life (years)
11	Operating Components	Doors	$332.23	4
12	Operating Components	Windshield Wipers and Washers	$247.06	1
13	Operating Components	Headlight Assy Lighting	$108.28	1
14	Operating Components	Dimmer switch Controls	$89.62	3
15	Operating Components	Speedometer Instruments	$101.68	3
16	Interior	Trim Panels		12
17	Interior	Headlining		12
18	Interior	Front End		12
19	Interior	Rear End		12
20	Interior	Passenger Info and Advertising		12
21	Interior	One Seat Insert Passenger Seats	$1,836.80	6
22	Interior	Driver’s Seat	$2,237.33	4
23	Interior	Rubber Floor Covering		12
24	Windows	Windshield	$2,500.00	12
25	Windows	Driver’s Side Window	$1,334.21	12
26	Windows	Side Windows	$2,281.84	12
27	Insulation	Insulation		
28	Ancillary Items	Dash Panels	$102.88	12
29	Ancillary Items	Visors	$232.34	6
30	Ancillary Items	Chime Exit Signal	$187.56	6
31	Ancillary Items	Outside Mirrors	$402.28	1
32	Ancillary Items	Inside Mirrors	$36.55	6
33	Passenger Assists	Front Doorway		12
34	Passenger Assists	Vestibule		12
35	Passenger Assists	Overhead		12
36	Passenger Assists	One Set Insert Longitudinal Seats	$45.92	6
37	Passenger Assists	Rear Doorway		12
38	Bumpers	Front Bumper	$1,091.12	12
39	Bumpers	Rear Bumper	$1,393.36	12
40	Destination Signs	Run Box Run Numbers		1
41	Destination Signs	Rear Route # Route Numbers	$4,223.00	3
42	Destination Signs	Front Main Auxiliary Destination Sign	$6,071.00	6
43	Destination Signs	Fare Collection Device		
44	Destination Signs	Wheelchair Lift	$21,000.00	12
45	Destination Signs	Wheelchair Restraints	$95.44	6
46	ITS Components	AVL		
47	ITS Components	APC		
48	ITS Components	Others		
49	Propulsion System	Engine Mounts	$88.96	3
50	Propulsion System	Accessories		
51	Propulsion System	Pump Hydraulic Drive	$1,056.76	3
52	Propulsion System	Engine	$19,320.00	6
53	Propulsion System	Radiator Cooling System	$3,865.00	6

Comp ID	Group	Component	Replacement Cost	Expected Life (years)
54	Propulsion System	Transmission	$18,232.00	4
55	Propulsion System	Muffler Cat Conv Exhaust System	$2,742.39	6
56	Propulsion System	EGR Emissions Control Devices	$396.19	3
57	Propulsion System	Reman Diff Axles and Differential	$2,014.75	6
58	Propulsion System	Sway Bar Suspension	$382.22	4
59	Propulsion System	Air Springs	$118.42	4
60	Propulsion System	Shock Absorbers	$119.23	4
61	Propulsion System	Steering Gear		
62	Propulsion System	Steering	$995.86	6
63	Brakes	Brake Chamber Actuators	$109.72	3
64	Brakes	Rear Axel Set Friction Material	$140.00	1
65	Brakes	Hubs	$890.87	6
66	Brakes	One Drums or Rotors	$110.00	1
67	Brakes	Compressor Air System	$1,008.66	3
68	Brakes	Wheels	$169.68	6
69	Brakes	Tires	$400.00	0.5
70	Fuel System	Fuel Tank	$2,027.08	6
71	Fuel System	Fuel Filler	$288.28	12
72	Electrical Components	Batteries	$89.35	2
73	Electrical Components	Master Battery Switch	$16.24	6
74	Electrical Components	Fire Detectors	$453.69	4
75	Electrical Components	Radio Noise Suppression		
76	Interior Climate Control	Master control a/c heat Controls	$1,000.00	6
77	Interior Climate Control	Plenums and Vents		12
78	Interior Climate Control	Filter Air Intakes	$10.66	1
79	Interior Climate Control	Radio & Public Address System	$164.23	4
99	Body/Structure	Other Overhaul Costs		12
99	Body/Body	Other Overhaul Costs	$180.26	12
99	Interior	Other Overhaul Costs	$3,000.00	6
99	Fare Collection	Other Overhaul Costs		12
99	Suspension	Other Overhaul Costs		12
99	Brakes	Other Overhaul Costs		12
99	Fuel System	Other Overhaul Costs		12
99	Electrical Components	Other Overhaul Costs	$1,742.44	6
99	Interior Climate Control	Other Overhaul Costs		12

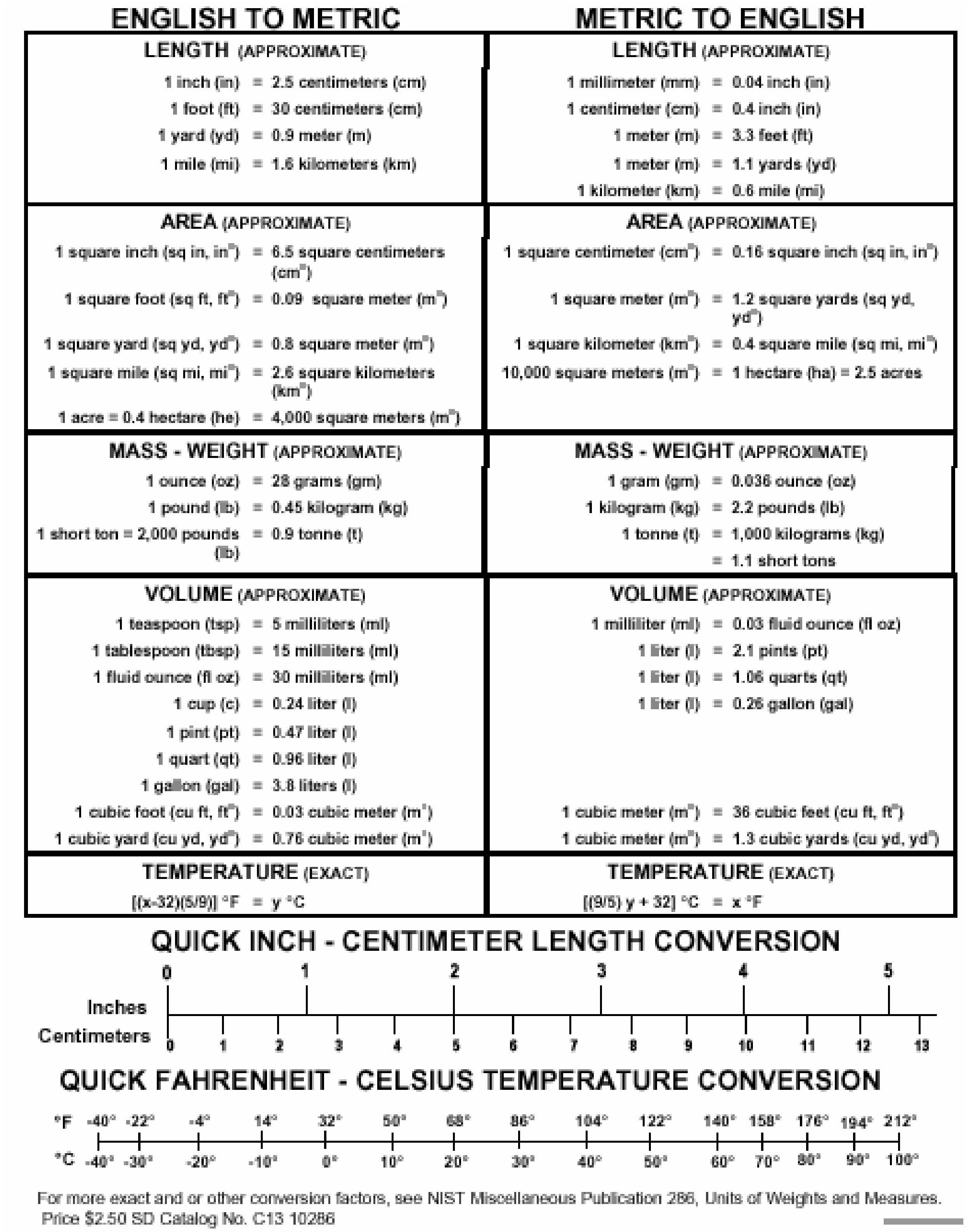
Table F-3
Vehicle Manufacturer Costs

Comp ID	Group	Component	Replacement Cost	Expected Life (years)
1	Body	Structure		12
2	Body	Exterior and Applied Panels	$310.00	12
3	Body	Paint		12

Comp ID	Group	Component	Replacement Cost	Expected Life (years)
4	Body	Interior		12
5	Body	Floor		12
6	Body	Steps and Stepwells		12
7	Body	Wheel Housings		12
8	Body	Exit Passenger Doors		12
9	Body	Service Compartment		
10	Body	Engine door Access Doors	$2,400.00	12
11	Operating Components	Doors		12
12	Operating Components	Windshield Wipers and Washers	$550.00	12
13	Operating Components	Headlight Assy Lighting	$150.00	12
14	Operating Components	Dimmer switch Controls		
15	Operating Components	Speedometer Instruments	$270.00	12
16	Interior	Trim Panels		12
17	Interior	Headlining		12
18	Interior	Front End		12
19	Interior	Rear End		12
20	Interior	Passenger Info and Advertising	$50.00	12
21	Interior	One Seat Insert Passenger Seats		12
22	Interior	Driver’s Seat		12
23	Interior	Rubber Floor Covering		12
24	Windows	Windshield	$720.00	12
25	Windows	Driver’s Side Window	$510.00	12
26	Windows	Side Windows	$630.00	12
27	Insulation	Insulation		
28	Ancillary Items	Dash Panels		12
29	Ancillary Items	Visors	$160.00	6
30	Ancillary Items	Chime Exit Signal		12
31	Ancillary Items	Outside Mirrors	$70.00	12
32	Ancillary Items	Inside Mirrors	$30.00	12
33	Passenger Assists	Front Doorway		12
34	Passenger Assists	Vestibule		12
35	Passenger Assists	Overhead		12
36	Passenger Assists	One Set Insert Longitudinal Seats		12
37	Passenger Assists	Rear Doorway		12
38	Bumpers	Front Bumper		12
39	Bumpers	Rear Bumper		12
40	Destination Signs	Run Box Run Numbers		12
41	Destination Signs	Rear Route # Route Numbers		12
42	Destination Signs	Front Main Auxiliary Destination Sign		12
43	Destination Signs	Fare Collection Device		12
44	Destination Signs	Wheelchair Lift		12
45	Destination Signs	Wheelchair Restraints		12
46	ITS Components	AVL		

Comp ID	Group	Component	Replacement Cost	Expected Life (years)
47	ITS Components	APC		
48	ITS Components	Others		
49	Propulsion System	Engine Mounts	$60.00	6
50	Propulsion System	Accessories	$2,800.00	6
51	Propulsion System	Pump Hydraulic Drive	$670.00	6
52	Propulsion System	Engine	$17,000.00	6
53	Propulsion System	Radiator Cooling System		12
54	Propulsion System	Transmission	$11,700.00	6
55	Propulsion System	Muffler Cat Conv Exhaust System	$750.00	12
56	Propulsion System	EGR Emissions Control Devices	$685.00	12
57	Propulsion System	Reman Diff Axles and Differential	$3,000.00	12
58	Propulsion System	Sway Bar Suspension		12
59	Propulsion System	Air Springs	$270.00	3
60	Propulsion System	Shock Absorbers	$260.00	3
61	Propulsion System	Steering Gear		
62	Propulsion System	Steering		12
63	Brakes	Brake Chamber Actuators	$140.00	6
64	Brakes	Rear Axel Set Friction Material	$200.00	3
65	Brakes	Hubs	$260.00	12
66	Brakes	One Drums or Rotors	$250.00	3
67	Brakes	Compressor Air System		12
68	Brakes	Wheels	$230.00	12
69	Brakes	Tires	$400.00	0.5
70	Fuel System	Fuel Tank		12
71	Fuel System	Fuel Filler		12
72	Electrical Components	Batteries	$100.00	3
73	Electrical Components	Master Battery Switch	$40.00	12
74	Electrical Components	Fire Detectors	$210.00	12
75	Electrical Components	Radio Noise Suppression		12
76	Interior Climate Control	Master control a/c heat Controls	$780.00	12
77	Interior Climate Control	Plenums and Vents		12
78	Interior Climate Control	Filter Air Intakes	$40.00	0.5
79	Interior Climate Control	Radio & Public Address System		12
99	Body/Structure	Other Overhaul Costs		12
99	Body/Body	Other Overhaul Costs	$310.00	12
99	Interior	Other Overhaul Costs		12
99	Fare Collection	Other Overhaul Costs		12
99	Suspension	Other Overhaul Costs		12
99	Brakes	Other Overhaul Costs		12
99	Fuel System	Other Overhaul Costs		12
99	Electrical Components	Other Overhaul Costs		12
99	Interior Climate Control	Other Overhaul Costs		

METRIC/ENGLISH CONVERSION FACTORS



ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)
1 pound (lb) = 0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg)
= 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION

Inches 0 1 2 3 4 5
Centimeters 0 1 2 3 4 5 6 7 8 9 10 11 12 13

QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F -40° -22° -4° 14° 32° 50° 68° 86° 104° 122° 140° 158° 176° 194° 212°
°C -40° -30° -20° -10° 0° 10° 20° 30° 40° 50° 60° 70° 80° 90° 100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286