# Vehicle Replacement Strategies: Opportunities for Efficiencies

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The economic outlook for transit indicates that the current scarcity both of operating and capital dollars will continue, and perhaps worsen. For example, many transit funding sources are growing at rates less than the inflation rate. Improving vehicle replacement strategies is one way to realize capital and operating cost savings. Faced with a planned vehicle replacement shortfall of $220 million over 10 years, the Los Angeles County Transportation Commission in conjunction with 13 Los Angeles County transit operators conducted a study to develop cost-effective vehicle replacement guidelines. The study efforts, which built on substantive prior nationwide capital replacement research, produced a simple yet effective means for evaluating cost impacts of alternative vehicle replacement schedules. The vehicle replacement methodology, which was developed comprehensively, incorporated vehicle procurement strategy, routine maintenance practices, and vehicle subsystem rebuild planning in the replacement decision. The vehicle replacement methodology and its associated data reasonably reflected the experience of the Los Angeles County operators. Cost savings could be identified in excess of $117 million in FY 1989 dollars over the next 10 years.

An FY 1988 nationwide transit vehicle replacement survey of 166 responding transit operators indicated that bus replacement decisions were generally based on availability of federal and local matching funds. Fully 96 percent of the respondents indicated that the federal guidelines of 12 years or 500,000 mi controlled their vehicle replacement decisions. Lack of local match monies was cited as the main reason for longer replacement cycles, when it occurred. Less than 12 percent of total respondents indicated that operating costs, major failures, or recent repairs entered into replacement decisions. Until FY 1989, the 13 Los Angeles County transit operators were not among this small percentage. These transit operators have identified more than $117 million in FY 1989 dollars in total cost savings over 10 years as a result of incorporating maintenance cost, capital expense, and subsystem rebuild and failure information into their vehicle replacement decision-making process.

The economic outlook for transit indicates that the current scarcity both of operating and capital dollars will continue, and perhaps worsen. For example, the funding ability of many transit funding sources is growing at a rate less than the inflation rate. Such financial constraints necessitate efficiencies in vehicle replacement strategies as a means for minimizing capital and operating expenditures of transit operators. Transit fleet managers control capital and operating costs through vehicle replacement, rehabilitation, and deployment decisions. It is essential that they have sound cost information and analytic techniques to support fleet replacement decisions.

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## LOS ANGELES COUNTY—A CASE STUDY

In July 1988, the Los Angeles County Transportation Commission (LACTC) identified a $220 million shortfall in funding needed to meet the capital replacement requirements of 13 Los Angeles County bus operators between FY 1990 and FY 2000. The estimated shortfall was based on current funding levels of $578 million and operator vehicle replacement practices and plans of $798 million. The estimated cost did not provide service expansion to meet the projected FY 2000 population increase of more than 2 million people in the County, nor did the estimate include capital expenditures needed to meet air quality mandates.

In response to the critical shortfall, LACTC and the 13 transit operators began to develop vehicle replacement guidelines that would more efficiently use available transit operating and capital financial resources.

### A Coach Replacement Methodology

Given the presence of real operating and capital financial constraints in the transit industry, particularly in Los Angeles, vehicle replacement guidelines should promote cost-effective decision making. Three key factors should be considered in determining from a low-cost perspective the retirement age of transit coaches:

- Capital costs, which are amortized across the useful life of a vehicle, decrease as vehicle age increases. Capital costs include the initial purchase price, major rebuild or remanufacture costs, minus any residual or salvage value at retirement.
- Basic maintenance costs, which reflect the higher costs of operation and repair associated with older vehicles, increase with vehicle age and accumulated mileage.
- Major subsystem rebuild costs can increase or decrease with age. Major rebuilds generally occur at fixed mileage intervals and provide additional years of useful vehicle life. The four subsystems in this category are engine, transmission, body, and frame, which have differing mileage intervals and costs. Any vehicle retirement schedule will reduce the benefits from one or more subsystem rebuilds. Replacement should be scheduled to minimize the overall rebuild cost across subsystems.

In the nationwide survey mentioned previously, costs in these three categories were significantly affected by vehicle replacement schedules, although they were not typically evaluated in the replacement decision. The transit coach replacement methodology recognizes the unique response to increase in vehicle age of each of these cost categories.

The vehicle replacement methodology shown in Figure 1 assumes that all transit dollars are equal, regardless of source or restrictions placed on that source. Combined annual equivalent cost (AEC) is used for comparing the total cost of different replacement cycles. This comparison determines the schedule of incurred cost and spreads the costs equally across the years of useful life. To identify the low-cost alternative, AEC values for different useful lives can also be compared.

Cost implications of each factor were defined using individual transit operator data alone, but available data were insufficient in some areas for each of the operators involved. Some related nationwide studies include the National Cooperative Transit Research and Development Program Report 10 (*1*) and studies for other public and private large-fleet managers. These prior efforts resulted in an extensive data base of vehicle operating and maintenance costs for 170 transit coach fleets containing more than 10,000 buses and 18,000 cars, trucks, and vans over the life of each vehicle or fleet.

This nationwide data base provided specific cost relationships such as slope of operating cost increase with age and mileage; cost versus miles between vehicle subsystem rebuilds; and salvage value of vehicles related to miles, years, and purchase price, to supplement available local information. Los Angeles County transit operators carefully examined their vehicle fleet deployment practices in light of the nationwide cost relationships, and critically reviewed the results. In all cases, the results reasonably reflected the experience and understanding of the transit operators, so they agreed to use this supplementary information in developing vehicle replacement guidelines locally.

### Vehicle Capital Cost

The capital procurement cost of a transit coach is a key cost consideration in a vehicle replacement decision. Because capital dollars purchase the use of a vehicle over a period of years, the purchase costs should be depreciated over the useful life of the vehicle. For a transit bus purchased with federal funds, the minimum depreciation schedule is 12 years or 500,000 mi. It is common practice to fully depreciate vehicles using the minimum federal guidelines even when vehicles are kept in service longer. Although this approach may be used for accounting purposes, the replacement analysis should depreciate vehicles over their full useful life. Other vehicles purchased using federal funds (e.g., vans, trucks, and automobiles) have a minimum depreciation schedule of 4 years or 100,000 mi.

A typical cost curve depicting average annual capital cost over a span of useful life options is shown in Figure 2. When vehicles have a significant salvage value, future sales revenue should also be spread over the vehicle's useful life to reduce overall costs. Salvage value information on transit buses less than 12 years old is not available. The transit bus market is highly specialized and resale markets for retired vehicles are often soft. The sales price of 6,500 buses retired and sold fell

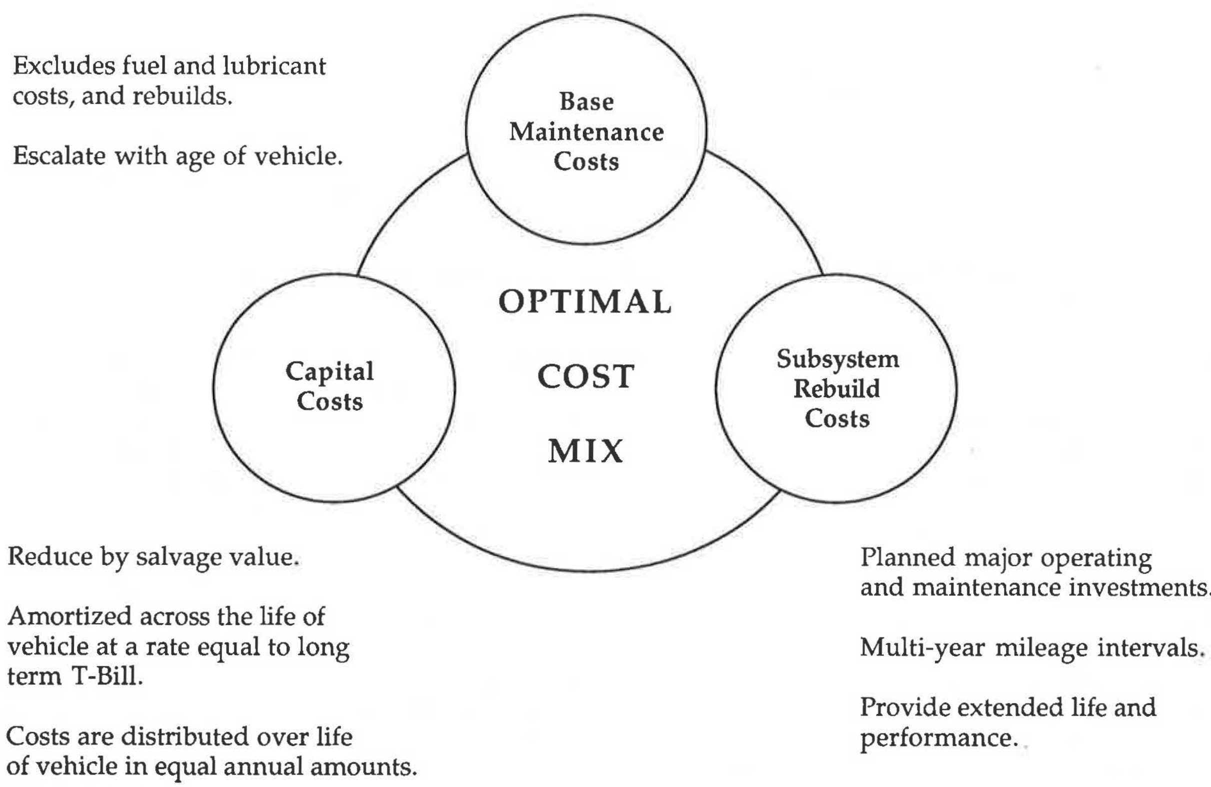


**FIGURE 1 Factors included in the Transit Vehicle Replacement Guidelines developed for Los Angeles County transit operators.**

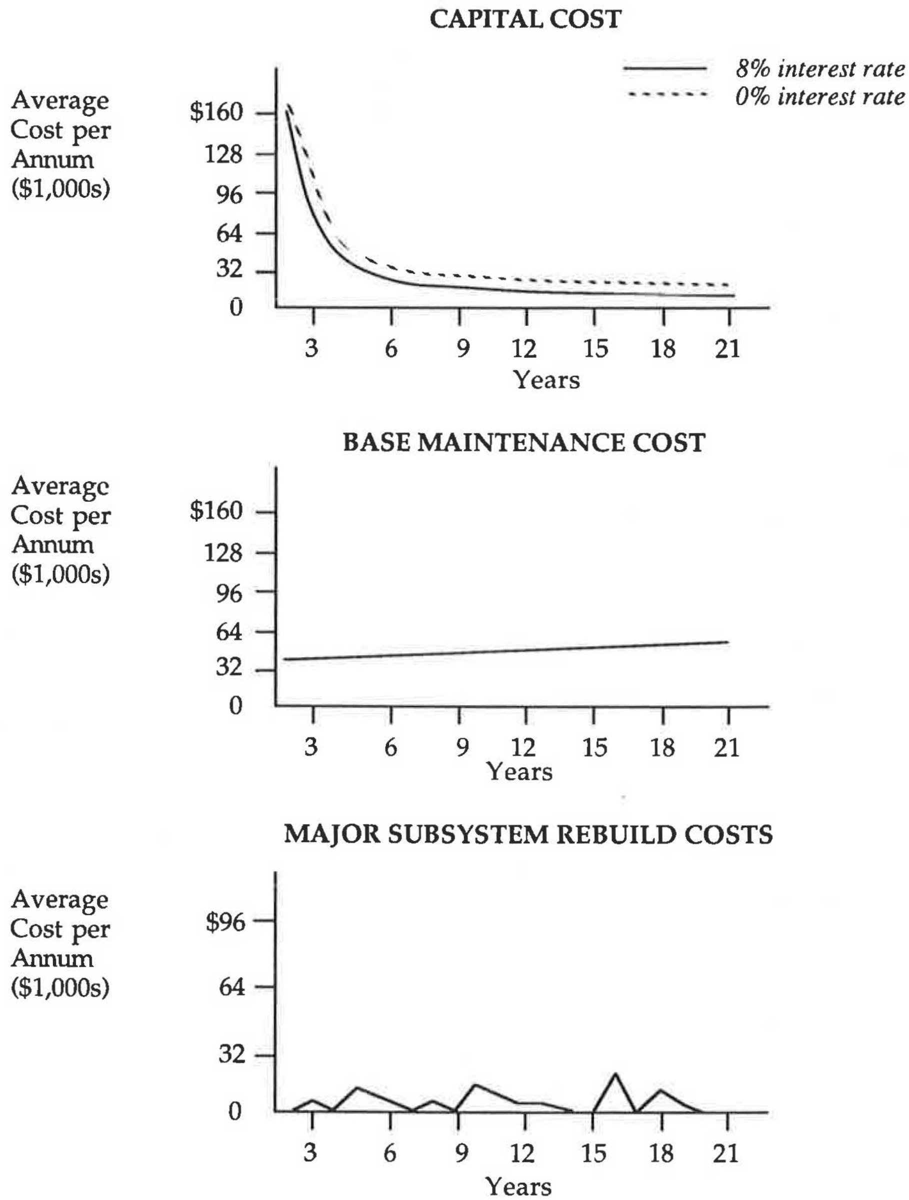


**FIGURE 2 Review of ways in which transit coach costs change over time, in constant-dollar terms.**

between $200 and $2,800 per coach. Although the salvage value is a revenue to be received in a future year, the vehicle replacement methodology examines all costs in current-year terms. When the salvage value is converted into present-day dollars, it is further diminished. For example, a salvage value of $1,000 in Year 12 is worth only $397 in present-day dollars. This amount, which compares to an initial purchase price of about $165,000 per coach, has little or no effect on the replacement strategy.

Although transit bus resale or salvage values appear to have little effect on overall investment cost, van, truck, and automobile resale values have a significant effect on their replacement strategies. Unlike the bus market, for these vehicles there is a strong second-hand support vehicle market with many potential buyers for most vehicles. On the basis of the resale of more than 8,500 support vehicles and examination of the automobile industry's blue book, a table of resale values was developed for use by the Los Angeles County transit operators in making replacement decisions, as presented in Table 1. The table assumes vehicles accumulate about 12,500 mi/year, but it can be adjusted to reflect other mileage rates. Given their large potential resale value, many support vehicles yield a smaller total cost when they are retired well before the 100,000-mi range.

### Basic Maintenance Costs (BMCs)

The nationwide research confirmed the widely held belief that BMCs for a vehicle increase with both age and accumulated mileage. Research published by the National Cooperative Transit Research and Development Board in 1988 addressed this issue explicitly. An analysis of the operating costs for 160 operating bus fleets indicated that BMCs increased with age,

TABLE 1 SALVAGE OR RESALE VALUE OF USED VEHICLES

| | Percent of Original Cost | | |
|---|---|---|---|
| Year | Automobiles | Compact Pickup | Trucks and Vans |
| 1 | 87.0 | 89.2 | 89.0 |
| 2 | 74.1 | 75.1 | 72.9 |
| 3 | 61.1 | 61.9 | 59.3 |
| 4 | 49.1 | 48.9 | 45.5 |
| 5 | 35.2 | 37.0 | 34.4 |
| 6 | 25.9 | 26.3 | 24.9 |
| 7 | 16.7 | 17.4 | 16.1 |
| 8 | 9.3 | 7.7 | 8.4 |
| 9 | 5.0 | 5.5 | 6.0 |
| 10 | 4.0 | 4.0 | 4.2 |

as shown in Figure 2. BMCs include labor, materials, and direct maintenance overhead for routine repair on all vehicle subsystems (e.g., engine cooling, compressed air, accessories, tires, suspension, drive train, electrical, air conditioning and heating, brakes, engine, and body), and inspection and servicing costs. Excluded are the costs of fuel, lubricants, and major subsystem rebuild activities.

The cost curve reasonably reflects the real cost escalation (i.e., the effect of inflation has been removed) of the GMC New Look fleet. Similar curves have been developed for more than 20 bus fleet types and 30 support fleet types used in the United States. The support fleet curve is substantially steeper than the bus maintenance cost curve, reflecting a shorter overall life expectancy.

Application of the vehicle replacement methodology uses the slope of the nationwide maintenance cost curve, the individual operator's wage rate and beginning cost per mile, the local comparative consumer price index, and the operator's fleet mix and running parameters (i.e., mileage, climate, and speed) to develop a BMC escalation curve by fleet. The cost escalation is in terms of FY 1988 constant dollars. The curve would be even steeper if current dollars were used.

### Major Subsystem Rebuild Costs

Major subsystem rebuild costs are multiyear operating cost investments that provide additional useful life for transit coaches. Major subsystem rebuilds are usually scheduled events, triggered by fixed mileage intervals. Nationwide, four types of bus subsystem rebuilds occur: engine, transmission, body, and frame. Rebuilds of these subsystems are generally an operating expense, but the expenditure results in additional years of reasonable performance.

Nationwide research includes data on the average number of miles between major subsystem rebuilds and the average cost of each rebuild by coach type. FY 1988 mileage and cost data (on the basis of 170 fleets) are presented in Table 2. These data can be adjusted to reflect each individual operator's practice and experience, or used as is if reasonable.

### Annual Equivalent Cost (AEC)

Capital, operating, and subsystem rebuild costs are calculated on the basis of planned or expected retirement age, and spread evenly over each year. For simplicity, all costs are stated in constant-year dollars because Los Angeles County operators did not want to forecast future inflation rates. The AEC approach shown in Figure 3 allows comparison of costs for different durations of useful life.

TABLE 2 NATIONAL AVERAGE FY 1988 DOLLAR COSTS AND SUBSYSTEM REBUILD FREQUENCIES ON THE BASIS OF 170 TRANSIT COACH FLEETS

| Vehicle Type | Base Operating Cost Per Mile | Engine Rebuild Miles | Engine Rebuild Costs | Transmission Rebuild Miles | Transmission Rebuild Costs | Major Body Rebuild Miles | Major Body Rebuild Costs | Major Frame Rebuild Miles | Major Frame Rebuild Costs |
|---|---|---|---|---|---|---|---|---|---|
| TMC/RTS 40' | $0.66 | 240,000 | $4,850 | 120,000 | $2,150 | 240,000 | $5,500 | 270,000 | $7,900 |
| FLXBLE METRO 40' | $0.66 | 240,000 | $4,850 | 120,000 | $2,150 | 240,000 | $5,500 | 270,000 | $7,900 |
| NEOPLAN 40' | $0.76 | 240,000 | $4,850 | 120,000 | $2,150 | 240,000 | $5,500 | 270,000 | $7,900 |
| CARPENTER 30' | $0.57 | 200,000 | $4,850 | 100,000 | $1,200 | 200,000 | $6,700 | 200,000 | $2,800 |
| GMC 40' or 35' | $0.66 | 225,000 | $4,300 | 80,000 | $1,900 | 270,000 | $5,200 | 270,000 | $4,900 |
| AMG/MAN 60' | $0.92 | 180,000 | $5,900 | 90,000 | $2,800 | 300,000 | $6,800 | 360,000 | $6,400 |
| GILLIG 40' | $0.65 | 240,000 | $4,850 | 150,000 | $2,150 | 200,000 | $6,700 | 200,000 | $2,800 |
| FLYER 35' or 40' | $0.76 | 240,000 | $4,850 | 150,000 | $2,200 | 240,000 | $6,700 | 270,000 | $2,800 |
| ORION 30' | $0.57 | 240,000 | $4,850 | 150,000 | $2,150 | 300,000 | $6,700 | 300,000 | $2,800 |
| AMG 40' | $0.93 | 200,000 | $4,850 | 100,000 | $2,550 | 200,000 | $6,700 | 150,000 | $2,800 |
| MCI 40' | $0.66 | 240,000 | $4,850 | 150,000 | $1,900 | 240,000 | $5,200 | 270,000 | $4,900 |
| EAGLE 40' | $0.78 | 320,000 | $5,000 | 200,000 | $2,350 | 360,000 | $6,750 | 360,000 | $2,850 |
| GMC/RTS | $0.66 | 180,000 | $5,000 | 120,000 | $2,350 | 240,000 | $6,750 | 240,000 | $2,850 |
| FLXBLE 870 | $0.65 | 200,000 | $4,850 | 120,000 | $4,900 | 240,000 | $6,700 | 240,000 | $2,950 |
| Gillig/Neoplan | 0.94 | 200,000 | $4,850 | 100,000 | $1,300 | 240,000 | $5,500 | 270,000 | $7,900 |

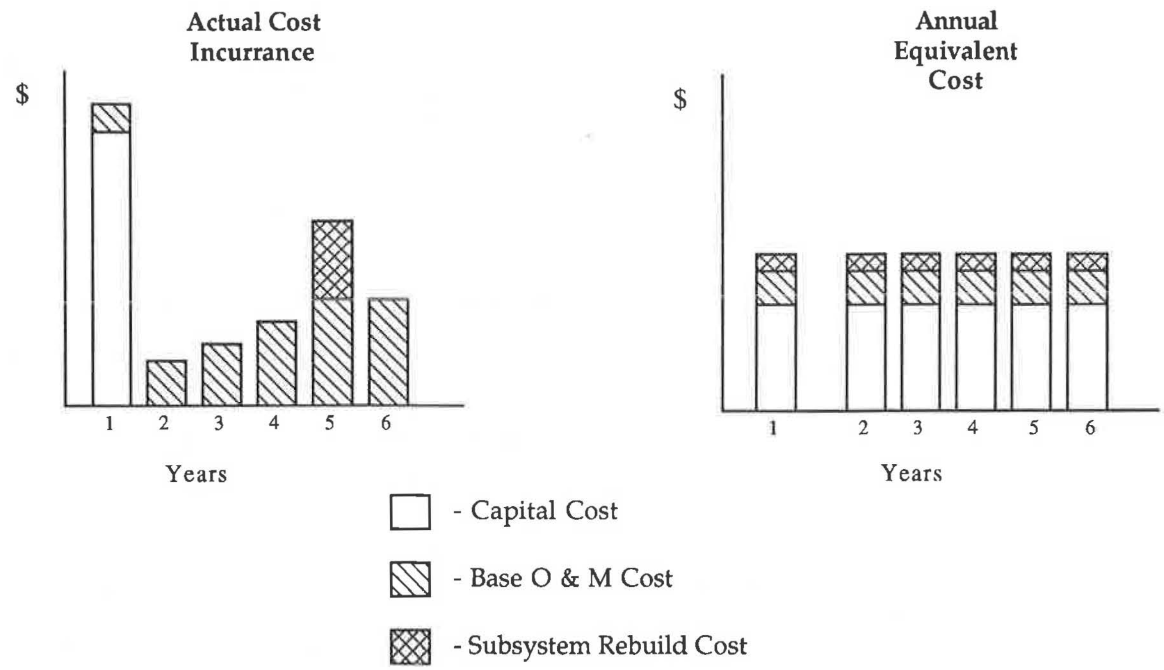


**FIGURE 3 Actual cost schedules versus AEC.**

### The Vehicle Replacement Methodology

The analytic vehicle replacement methodology developed for Los Angeles County transit operators requires 14 straight-forward steps to assess the low-cost retirement year. The first four steps develop an AEC for any planned retirement cycle. The subsequent 10 steps define the lowest cost retirement year. An example of the information input required for applying the methodology is as follows:

*Long Beach Transit Fleet Data*

| | |
|---|---|
| Fleet type | GMC RTS (4700) |
| Active buses | 13 |
| Annual miles | 48,000 |
| Interest rate | 8.00% |
| Purchase price | $93,155 |
| Maintenance cost per mile | $0.66 |
| Engine rebuild miles | 180,000 |
| Engine rebuild cost | $5,000 |
| Transmission rebuild miles | 120,000 |
| Transmission rebuild cost | $2,350 |
| Body rebuild miles | 240,000 |
| Body rebuild cost | $6,750 |
| Frame rebuild miles | 240,000 |
| Frame rebuild cost | $2,850 |

The mileage and cost data presented in Table 2 may be used to supplement local information if all elements are not readily available. The initial four steps in the transit coach replacement methodology are as follows.

### Step 1: Determine Annual Capital Cost (ACC) per Vehicle

The first step is to determine the ACC per bus in the specific fleet being analyzed. (Note that each fleet or vehicle type is analyzed separately.) This quantity is a function of the initial purchase price, the salvage value, the expected useful life, and the long-term interest rate.

As part of the AEC approach, the total purchase price is amortized over the vehicle's useful life. The ACC is actually incurred in a single year, but the expenditure is deemed an investment with value (both capital and imputed interest) consumed annually over the useful life. Also, the salvage value is gained in a later year and must be discounted to current-year dollars. The imputed interest rate used for the purposes of this analysis is the long-term U.S. Treasury bill rate, as reported by local newspapers.

The equation for calculating the ACC is

$$\text{ACC} = (\text{initial purchase price} * \text{amortization factor}) - (\text{salvage value} * \text{sinking fund factor})$$

### Step 2: Calculate Annual Basic Maintenance Costs (BMCs)

For the purposes of this application, the annual BMCs include all vehicle maintenance costs except for fuel and lubricants, which do not have a statistical correlation with vehicle age, and major subsystem rebuild costs. This breakdown is sometimes difficult to derive from local transit operator records. Nationwide data for cost figures by vehicle type presented in Table 2 can be adjusted to local conditions.

The beginning-year maintenance costs are applied to the cost growth formula accounting for real-cost increases related to vehicle age. All maintenance costs are stated in current-dollar terms without adjustment for future inflation. The cost formula is based on mileage driven and accumulated at retirement.

$$BMC_m = \left[1 + \left(\{[(\text{cumulative miles at retirement} - \text{average miles per year})/100{,}000]/2\} * 0.0353\right)\right] * (\text{initial cost per mile}) * (\text{average miles driven per year})$$

If bus mileage information is not available, annual information can be used, as follows:

$$BMC_a = \left(1 + \{[(\text{useful life in years} - 1)/2] * 0.0116\}\right) * (\text{initial cost per year per vehicle})$$

This formula assumes about 33,000 mi per vehicle per year, through retirement. The cost escalation factor of 0.0116 can be adjusted to reflect different mileage accumulation rates.

### Step 3: Determine Subsystem Rebuild Costs

Subsystem repair and rebuild costs change directly with vehicle age (i.e., the accumulation of mileage rather than years) and are calculated separately. This step requires two calculations, first determining the total subsystem rebuild cost:

$$E = \sum_{j=1}^{4} (\text{average cost of rebuild}_j) * (\text{cumulative miles at retirement})/(\text{miles between subsystem rebuild}_j)$$

where $j$ represents each rebuild type (i.e., engine, body, transmission, and frame). Note that the ratio of cumulative miles to miles between subsystem rebuilds should be rounded down to the nearest whole number before multiplying by cost. The second step is calculating

(Total major rebuild cost)/(useful vehicle life)

### Step 4: Determine Current AEC Bus Cost

The results of Steps 1, 2, and 3 are added to determine the total AEC for the existing bus replacement practice. Multiplied by the number of buses in the fleet, this value determines total current AEC.

$$AEC_t = (\text{annual capital cost} + \text{basic maintenance cost} + \text{subsystem rebuild cost}) * (\text{number of buses in fleet})$$

### Comparison of Bus AEC Costs

These four steps can be applied for the range of potential vehicle replacement years (e.g., 8 to 24 years), and the relative AEC cost compared for each year. Application of the Long Beach Transit GMC RTS fleet data presented in Table 3 yields the AEC cost curve shown in Figure 4. As shown, the lowest cost replacement period for this fleet is 15.5 years. In the case examined, all four subsystem rebuilds are scheduled to occur around that time period, should the vehicle be retained. Should the vehicle continue in service, at no time will the average


**FIGURE 4 AEC of different fleet retirement schedules for Long Beach Transit's GMC RTS fleet.**

AEC be less than it is at 15.5 years. When Long Beach Transit planning staff reviewed these results, they indicated that maintenance management had noted that significant expenditures were required to maintain this fleet in the 15th year, and requested direction on the retirement issue. Long Beach Transit frequently operates vehicles for more than 18 years, albeit earlier retirement may be warranted from a cost perspective.

When the replacement guidelines were applied to each fleet owned by the 13 Los Angeles County transit operators, the guidelines presented a less costly replacement alternative, which required replacing the vehicle 2 to 4 years earlier or later than planned. The net result of the new replacement plan is a cost savings of $117 million (FY 1989 dollars) over 10 years.

Another critical benefit of the vehicle replacement methodology is that it brings together all aspects of fleet management. Vehicle replacement, subsystem rebuild, and routine maintenance are all assessed in the overall fleet and cost management decisions. Maintenance, planning, grants, information systems, finance, accounting, and top management all converse and have input into a logical and defensible vehicle replacement strategy. Managers at each level are required to evaluate the full field of issues that impact vehicle replacement.

- Should vehicles operate more or fewer miles to correlate low-cost opportunities with funding availability?
- Should fleets be redeployed to better realize the low-cost opportunities of each specific fleet type?
- Should fleets with problems be lightly used (extending their lives) or should their use be accelerated to speed up retirement?
- Should maintenance practices be changed relative to subsystem rebuild practices?
- Can vehicle procurement practices be streamlined to ensure that costly replacement delays do not occur?
- Given the opportunity for cost savings, can the availability of investment resources be influenced to reduce cost?

These questions are just a few of the questions that Los Angeles transit operators are bringing up in response to the established vehicle replacement guidelines.

Another 10 steps are used to evaluate the Los Angeles fleet strategies. These additional steps mathematically define the low-cost replacement point without the need for applying the initial four steps repeatedly. The additional formulas also allow the operator to schedule mileage accumulation over a curve, rather than only a flat number of miles operated per year over the fleet's useful life. This feature can be important as many new fleets operate high mileage in the early years, and significantly fewer miles toward retirement. Even so, the first four steps afford a sound and simple means of evaluating vehicle replacement schedule alternatives from a comprehensive cost perspective.

## DIAL-A-RIDE AND SUPPORT FLEET METHODS

The Dial-a-Ride and support vehicle methodologies focus on BMCs and ACCs—major subsystem rebuilds are not common with these fleets. When rebuilds occur, they are included in the BMCs. Again, the vehicle replacement methodology attempts to define the low total cost replacement cycle.

For each fleet type, the data required for support and van fleets include fleet size, purchase price per vehicle, average annual miles, accumulated miles at retirement (optional), and maintenance cost per mile. The analytic vehicle replacement methodology for support fleets requires the repetition of three straightforward steps.

### Step 1: Determine ACC per Vehicle

Unlike transit coaches, support fleets may have a significant residual or salvage value at retirement (Table 1). The ACC per vehicle is

$$\text{ACC} = (\text{initial purchase price} * \text{amortization factor}) - (\text{salvage value} * \text{sinking fund factor})$$

Again, the salvage value, sinking fund, and amortization factors should be based on the expected useful life of the vehicle and the current long-term T-Bill interest rate.

### Step 2: Calculate the Vehicle Annual Maintenance Cost (AMC)

As with the transit coaches, demand response and support fleets also cost more to maintain as they age and accumulate miles. The AMC for vans and support vehicles includes all vehicle maintenance and rebuild costs except for fuel and lubricants. The cost formula for AMC as the vehicle ages is

$$\text{AMC}_m = \{1 + [(\text{useful life}/2) * \text{age factor}]\} * (\text{initial cost per mile}) * (\text{average miles per year})$$

If mileage information is not available, annual information can be used.

$$\text{AMC}_a = \{1 + [(\text{useful life}/2) * \text{age factor}]\} * (\text{initial cost per year per vehicle})$$

The age factors used in the formulas are as follows:

- Vans: 0.0300
- Automobiles: 0.0167
- Trucks: 0.0213

### Step 3: Determine Current Vehicle AEC

The results of Steps 1 and 2 are summed to determine the total AEC for the existing vehicle replacement practice. This value is multiplied by the number of vehicles in the fleet to determine total current AEC cost.

$$\text{AEC}_t = (\text{annual capital cost} + \text{basic maintenance cost}) * (\text{number of vehicles in fleet})$$

This cost is to be compared with alternative vehicle replacement cycle costs. A simple approach to finding the lowest

AEC cost alternative is both to increase and decrease the replacement year period in Steps 1 and 2. If either change results in a lower AEC cost than the current schedule, continue to increase or decrease correspondingly until the cost trend reverses. The lowest cost cycle will be the year preceding the reversal.

Unlike bus replacement for which the most common low-cost result is to extend useful life modestly, support fleet analysis suggests that retirement and resale be accelerated. There are several reasons for this result in Los Angeles:

- Most operators replaced support fleets after 100,000 mi or 5 years.
- Operating costs increase rapidly for support vehicles, particularly in Years 4 and 5.
- Resale values are high in early years, but rapidly diminish in Years 4 and 5.

In most cases, a 3.5- to 4-year retirement period yielded the lowest total cost for support vehicles. In mileage terms, this choice reflects about 55,000 to 65,000 mi per vehicle in Los Angeles. Overall, the replacement guidelines identified about $8 million (FY 1989 dollars) in cost savings over the next 10 years.

## ONGOING VEHICLE REPLACEMENT RESEARCH IN LOS ANGELES

Los Angeles transit concerns with regard to vehicle replacement and meeting of anticipated funding shortfalls are not fully resolved. This study provides only part of the solution. The LACTC, 13 transit operators, and consulting team are continuing to refine and implement solutions to vehicle replacement needs. Ongoing discussions focus on ways to use the guidelines in establishing priorities for capital funding requests among operators in Los Angeles County, identifying and analyzing alternative capital financing mechanisms that overall will help realize the greatest cost savings, and refining and automating the replacement guidelines.

Automation of the guidelines allows the opportunity for greater sophistication without further encumbering scarce staff and data resources. Some enhancements under consideration include

- Developing an algorithm that allows analysis of alternative funding mechanisms and their cost, when attempting to replace vehicles at the low-cost time interval and when sufficient funds are unavailable.
- Changing the maintenance cost formula mathematically to better reflect real cost incurrence, which is an $S$ curve, rather than the straight line used in the manual method presented here. Warranties result in low initial vehicle maintenance costs, then normal real cost escalation occurs, and finally costs taper off in the final 2 years of vehicle life as some repairs are foregone.
- Revising the subsystem rebuild function to allow for different rebuild strategies in later years.

Although work continues in the area of vehicle replacement strategies in Los Angeles and across the country, as an industry transit operators and funding agencies should closely examine vehicle replacement decisions from a total cost containment perspective. This process requires examination of the full gamut of fleet deployment, utilization, maintenance, and procurement practices.

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## REFERENCE

1. *NCTRP Report 10: Public Transit Bus Maintenance Manpower Planning*. TRB, National Research Council, Washington, D.C., 1984.

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