LIFE-CYCLE COSTING FOR PROCUREMENT OF SMALL BUSES

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16. Abstract

Life-cycle costing is a technique for objectively incorporating the costs of ownership of equipment in the procurement selection process. It is an accepted alternative to low initial price for selection of transit rolling stock. To be used in procurement, the evaluation procedure must be described in the bidders' information and the procedure and data used must be based on an established relationship to the costs of owning and operating the equipment. Forecasts of future costs for maintenance and fuel may be based on experience obtained either in a testing program or final normal revenue service operation. Realistic assessments of future operating environment and requirements, and consistent applications of procedures and cost parameters, tend to minimize the risk that errors in estimates of future costs will result in an incorrect selection. Use of life-cycle costing reduces the probability that low-priced, but inappropriate, vehicles will be selected for transit service and encourages vendors to incorporate cost-effective improvements in tendered vehicles.

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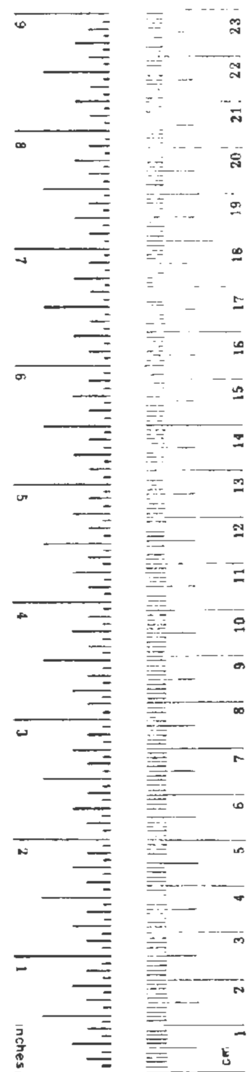
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

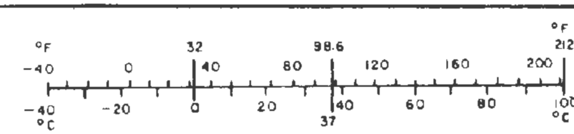
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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FOR PROCUREMENT
OF SMALL BUSES

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FOREWORD

Life-cycle costing is the technique of estimating the total cost of owning and operating a piece of equipment throughout a period of ownership. The predicted life-cycle cost provides a basis for planning decisions and for comparing different equipment or different design features on similar equipment. These guidelines for life-cycle costing of small transit buses focus on the comparative evaluation of competing bus models and explain the use of life-cycle costs as an element of procurement decisions.

The guidelines discuss the many factors that must be considered in the development of procurement procedures using life-cycle costs. A simplified example of life-cycle costing illustrates the computations and suggests sources for the data. The example uses hypothetical vehicles and conditions, and includes a number of simplifying assumptions, such as a uniform life for each of the bus models and that their passenger capacity is the same. The transit operator who applies life-cycle costing must adapt the procedure to actual conditions and requirements.

The objective of using life-cycle costing in procurement is to obtain a product that performs economically and well. The manufacturer is encouraged to offer a product that is well suited for a particular application, rather than one that meets minimum requirements at the lowest price. The operator should be prepared to accept innovations and departures from conventional practices, with the prospect of being able to provide better transit service.

I. LIFE-CYCLE COSTING

Decisions for selecting and purchasing equipment are usually based on cost and level of performance of the product. The service the equipment is required to perform also influences decisions on equipment acquisition and operation, because the conditions of service are known to affect costs of operation. However, to acquire the most economical equipment, it is not necessary to restrict the number of pieces of equipment, the useful life of the equipment, or its many engineering and material features. Instead, objective procedures for evaluating not only the initial costs of the equipment, but also the costs of owning and operating it, may be used. The choice of method for determining the cost may depend on several considerations such as legal constraints, the nature of the market for the product, the agency budget, and the purchaser's experience.

Life-cycle costing (LCC) is one of several methods for selecting equipment on the basis of the lowest cost for a required level of service. The main advantage of LCC is that total life costs are determined in a straightforward analytical way. Its disadvantages include the time and effort required for the computations and the need for data to predict operational cost and performance.

DEFINITION OF LIFE-CYCLE COSTING

The Office of Management and Budget defines Life-Cycle Cost as:

> The sum total of the direct, indirect, recurring, non-recurring, and other related costs incurred, or estimated to be incurred, in the design, development, production, operation, maintenance and support of a major system over its anticipated useful life.(1)

Life-cycle costing is a method for comparing and evaluating similar products that incorporates the estimated cost of maintaining and operating each product during its effective life. The legal basis for the use of LCC and similar techniques in procurement at the Federal level is found in the United States Code, Title 10, Section 2305(c), and Title 41, Section 253, which state that 'award shall be made...to the responsible bidder whose bid...will be most advantageous to the United States, price and other factors considered.' By considering factors in addition to initial purchase price, LCC provides a broader and sounder basis for comparison.

These additional factors can be termed the costs of ownership. In many cases, the initial purchase price of an item is only a fraction of the total cost of operating and maintaining that item. For example, the cost to purchase a transit bus is approximately the cost of operating it — labor,

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[1] Circular No. A-109, Executive Office of the President, Office of Management and Budget, Washington, DC, April 5, 1976.

fuel, service, and repair parts — for one year. LCC provides a method for systematically aggregating these costs of ownership that are incurred during the useful life of a product.

To apply LCC, the buyer must have an adequate basis for a forecast of total costs of ownership. The forecast must be developed for each product under consideration and should account for at least the following factors:

- Initial price;
- Operating costs;
- Productivity;
- Useful life; and
- Salvage value.

LCC PROCUREMENT EXPERIENCE

The use of life-cycle costing in the procurement process is not new in either government or industry. In 1963, the Department of Defense (DOD) took the initiative in the use of LCC on the Federal level.(2) Ten years later, the General Accounting Office recommended that DOD increase its use of LCC and that civilian agencies review their programs to identify areas where LCC would be applicable.(3)

In private industry, the concept of LCC has been used to guide the preparation of specifications and the acquisition of capital equipment, such as power generators, boilers, and process machinery. State and local government levels have long recognized that equipment with a higher initial price may, in fact, be more economical to own. They have applied the principal of LCC in the procurement of large items, such as graders, dump trucks and front-end loaders, and to parts and components, such as brake shoes and diesel fuel-injector seals. But this has been done usually by specifying a particular model with a reputation for long and economical service rather than by competitive life-cycle cost evaluation.

Examples of items that have been procured on an LCC basis include:

- Transit Buses, Ottawa-Carleton Regional Transit Commission;(4)

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[2] Casebook - Life Cycle Costing in Equipment Procurement, pg. 1, U.S. Department of Defense, Washington, D.C., July 1970.

[3] A Review of GAO Decisions of Life Cycle Costing, DOD Contract No. SD-321, Logistics Management Institute, Washington, DC, June 1974.

[4] Ottawa-Carleton Transit Procedure for Evaluation of Tenders, American Transit Association, Spring Conference, Washington, DC, May 1974.

- Electric Storage Batteries, Department of Defense;(5)
- Diesel Engines, Department of Defense;(6)
- Aircraft Tires, Department of Defense;(7)
- Automobiles, Southern California Rapid Transit District and County of Los Angeles;(8)
- Air Conditioners, General Services Administration;(9)
- Light Bulbs, Energy Research and Development Administration;(10)
- Buildings, General Services Adminstration;(11) and
- Computer Peripherals, Department of Defense.(12)

This partial list suggests the variety of items to which LCC applies. Although each agency uses a different approach in cost analysis, the purpose is the same for each — to purchase the item which offers the lowest life cycle cost or the most economical service.

COMPARISON OF LCC AND LOW-BID PROCUREMENT

The low-bid-price approach to purchasing equipment is based on two major considerations — responsiveness to the specification, and the amount of the initial price. The buyer develops a detailed specification describing the required item and publishes a Request for Proposals (RFP) or an Invitation for Bids (IFB). Vendors submit their proposals and the award is made to the party that offers the specified item at the lowest initial price.

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[5] Life-Cycle Costing Guide, Experimental Technology Incentives Program, National Bureau of Standards, Logistics Management Insitute, Washington, D.C.

[6] Casebook, op. cit.

[7] Ibid.

[8] E.W. Stanley, Southern California Rapid Transit District, letter, dated June 1, 1978.

[9] Life-Cycle Costing Guide, op. cit.

[10] K. Riegel, Energy Research and Development Administration.

[11] Life-Cycle Costing in the Public Buildings Service, General Services Administration, Washington, D.C., September 1975.

[12] Casebook, op. cit.

Specifications

Life-cycle costing is similar to low-bid procurement in that the buyer must specify the requirements and publish an RFP or IFB. In LCC, the specification may be a simple performance-oriented statement. For example, in the performance specification for brakes of a motor vehicle, a maximum emergency stopping distance from a speed of X m.p.h., might be sufficient. But in the detailed specification for low-bid-price procurement, the width, circumference, application pressure and other design details for brake assemblies, or the model number of an acceptable assembly, are included.

In low-bid procurement, the specification establishes the minimum configuration of the product. The specification assures the purchaser of obtaining a product that is both suitable and economical for the required operation. The bidder's objective is to offer a product which conforms to the specification, but at the minimum practical initial price. This is done so that the bid will be competitive. Therefore, in low-bid-price procurement, the specification must be comprehensive and very descriptive in order to accomplish the purchaser's objective.

In the LCC method, it is not necessary to include in the specification provisions that are intended to insure economical operation, because the estimate of operating cost is a major element in the evaluation. All that is necessary for the specification are broadly-stated performance requirements. This gives the purchaser greater diversity of products from which to choose, with the final selection depending, at least in part, on the intended use of the product.

Data For Evaluation

Low-bid and LCC procurement also differ as to data needed for evaluation. Low-bid procurement does not call for operating data; although, operating experience probably will have influenced the specification provisions. But the LCC method of evaluation requires detailed information on the operating cost of the product. Complete data must be available for each product being evaluated. Such data may come from a variety of sources — experience of other operators, specially conducted tests, manufacturers' records or validated predictive models. For each source, the data must include a full description of the operating environment and the conditions under which the data were developed. This is necessary to assure the evaluating agency of the validity of the data and to permit adjustments for differences in the assumed future conditions.

Selection Decision

In low-bid procurement the selection decision is based on the purchase price, which is clear and specific. For LCC procurement, selection is based on the aggregate of several elements that depend on predicted future conditions and the use of sound judgement. When examining data for different products, it is important to know whether the information for each was taken under similar environmental conditions. It is necessary to use these data in an unbiased way, so that the comparison of total life-cycle costs of different products is valid. And, as with all statistical data, the analyst must understand that when comparing products, small differences in costs of similar products may not be significant.

LIMITATIONS OF LCC

An understanding of the limitations of life-cycle costing is important both in the decision to use LCC and in the LCC evaluation. These limitations offset some of the benefits of LCC and should be considered before undertaking an LCC procurement.

Operating Data Needs

The obligation to collect and compile data, in a manner such that each competing product is treated fairly and equitably, places an extra burden on the purchaser. The purchaser may incur added costs for testing and data collection. Also, some smaller purchasing entities may be unable to conduct tests of competing products and, therefore, cannot perform an LCC procurement unless an adequate source of data exists.

For new products, there may not be sufficient data, because of the short time available for gaining operating experience. In such cases, special provisions will be needed to insure that promising new entries are not excluded from competition. Similarly, modifications and improvements to established products may raise major questions about the applicability of data based on past operating experience. In the case of product improvements that are claimed to reduce operating costs, the data must be carefully adjusted and justified.

Applicability

The use of LCC for procurement is practically limited to those products where the expected savings are large enough to offset the costs of the LCC analysis. Products with high operating or recurring costs are more likely to warrant LCC analysis than those with comparatively low costs. Similarly, purchase of large quantities involving small unit savings may justify use of LCC.

Uncertainty of Results

In some cases, the results of LCC analyses may be inconclusive or subject to reversal when the conditions established for the evaluation are changed. Such situations arise because some of the elements of the analyses, such as future maintenance costs or the price of motor fuel, are at best educated guesses and subject to statistical variability and uncontrollable changes. The possibility of extremely close life-cycle costs on two or more similar products must be recognized by the purchasing authorities. Very small differences between LCC's, which include predicted future costs, should not be permitted to control the selection process, as they would in a low-bid procurement. Instead, an evaluation procedure based on LCC and other objective criteria should be carefully specified in the IFB (See Chapter IV). Otherwise, the chances of protests and litigation are increased.

Legal Consideration

Titles 10 and 41 of the United States Code (USC) establish the general rules and conditions for Federal procurement. Nothing in these statutes can be construed to preclude the use of life-cycle costing as an element in the procurement process. USC stipulates, however, that formally advertised procurements must be conducted in a manner that is fair to all competitors. Fair competition means, among other things, that the terms and conditions of the procurement, including bid evaluation methods, standards and criteria, must be specified in the information given to all bidders for their use in preparing bids. USC charges the purchasing authority with the responsibility for conducting the procurement action so as to insure that the greatest value is received in terms of both performance and costs. Thus, the award may be to a higher priced product providing that the anticipated performance of that product is objectively shown to have a greater value to the purchaser, as determined by using the announced evaluation procedures. Some state and local laws however may constrain the use of LCC as a formal bid evaluation procedure. Therefore, contracting officers in state and local governmental agencies and public corporations should seek legal opinion on the admissibility of LCC and limitations on its use by their organizations.

Experience

At present, there is limited, but continually expanding, experience in the techniques required for LCC analysis. As the LCC concept and techniques are used by more purchasing entities and applied to more products, this limitation should disappear.

PROCUREMENT OF TRANSIT BUSES

The transit operator generally has two major concerns when procuring vehicles. These concerns are for level of service and minimum total cost. The vehicles must provide the desired level of service in terms of operating characteristics, reliability, convenience, and passenger comfort. And, the service must be provided at the least total vehicle-related cost.

In low-bid procurement the two objectives of satisfactory service and low cost are met by preparing a detailed engineering specification to establish minimum characteristics of the vehicles. The lowest priced vehicles that conform to the specification are then selected.

This low-bid procedure has been used effectively for many years for the purchase of conventional urban transit coaches, (i.e., diesel-powered coaches, 35 to 40 feet in length and seating 40 to 55 passengers). Such coaches are produced by a limited number of manufacturers and are designed for the urban transit environment. Changes in vehicle designs have occurred gradually and most operators are experienced in maintaining and operating such equipment. The transit property is, therefore, well prepared to write specifications and to evaluate proposals.

For small transit buses, a different situation exists. These buses vary from van-type vehicles to coaches less than 35 feet long. Small buses are classified as light-, medium-, and heavy-duty depending upon their size, cost and anticipated service life, and the type of service for which they are appropriate. Though many of these vehicles are owned by urban transit properties, they are also used in private businesses and by cities, suburban and rural communities, and a host of service agencies for the elderly and handicapped. Service requirements range from fixed-route, fixed-schedule, center-city operations to demand responsive operations involving long distances in rural areas. This vehicle market is served by many manufacturers offering vehicle components, stock vehicles and a wide spectrum of modification to stock vehicles. In general, whether a stock vehicle or a custom modification, the bus is not specifically designed for the type of service it will enter. The result is that, in purchasing small buses, the operator is offered a multitude of possible choices. These vehicles vary greatly in initial cost and range from well-suited to totally inappropriate for the intended operation. Due to lack of experience with the variety and broad range of features in small transit buses, the operator may be poorly prepared to write a detailed specification describing buses that are both economical to operate and well-suited for the particular mode and area of operation.

APPLICATION OF LCC TO SMALL BUSES

The life-cycle costing method offers certain advantages over the low-bid procedure when purchasing small buses. LCC permits the operator to rely on a broad performance specification, and to make a selection based on the predicted total cost of owning and operating the vehicle or equipment. Unlike low-bid procurement, LCC does not limit the bidder to specific vehicle design features. Instead, LCC insures that all aspects of maintenance and operation are considered in making the final selection.

Small transit buses are relatively short-lived; therefore, it is practical to establish testing procedures because the length of tests can be correspondingly short. Testing and collection of cost and operating data can be performed under operational conditions to insure relevant data. By testing a vehicle in the actual operating environment, or by adjusting for site differences in operating data obtained from other locations, the buyer can be confident that the selected model will conform to the estimated life cost for that particular situation. Testing in actual transit service is important in view of the variety of products on the market, and the fact that a particular model often performs differently under different conditions. Terrain and climate vary widely and affect vehicle maintenance costs. In addition, preventive maintenance procedures, such as frequency of lubrication, oil changes, or component replacement, alter maintenance costs. Service differences, such as stopping frequency and average operating speed, affect both fuel consumption rates and maintenance requirements.

Several hundred transit properties and other agencies are currently operating small buses. Although the data vary greatly from place to place, with appropriate adjustments they provide a basis for initiating LCC analyses. While much of the data indicate unsatisfactory experience with small buses, there is substantial evidence that the poor performance usually has occurred where the buses in use were not suited to the oeprating environment. The use of LCC analysis prior to purchase is intended to avoid such inappropriate selections. Furthermore, use of LCC in the procurement process will encourage manufacturers to offer vehicles with service characteristics and components that are suitable for the operating environment, and to correct observed deficiencies and cost-incurring features.

The future demand for small, economical transit vehicles will be based on trends that are already evident. Energy shortages have made transit operators acutely aware of the need to conserve fuel. Where a smaller, lighter vehicle can provide the required service, small buses may permit savings in both fuel and capital invested. Also, there is significant pressure to develop transit service that provides an attractive and energy efficient alternative to increasingly expensive private automobiles. Such service will include feeder and community circulation routes for which small buses are well-suited.

Concern over transportation for elderly and handicapped citizens is creating an expanded demand for small buses to operate for special service needs. Demand-responsive and community-circulation service modes do not warrant the use of large coaches. Moreover, these buses often operate in areas where lighter weight and greater maneuverability are required.

Service Requirements

The use of vehicles that are well-suited to the operational environment is a prerequisite for economical and effective transit service. Service requirements state the conditions under which a vehicle will operate. These requirements range from interior accommodations to traffic and climatic environment. Service requirements also include vehicle reliability, and driver comfort and freedom from fatigue.

For small buses, the service environment ranges from infrequently travelled rural roads to the dense traffic of large-city central business districts. The passenger demand can include three passengers per hour or sixty, and may require accessibility for severely handicapped persons.

In small bus procurement based on LCC, service requirements are reflected in both the performance specification and the computation of life-cycle costs. The specification must cover those aspects that are independent of costs and those to which costs are insensitive, such as ride quality, accessibility for the handicapped, and interior lighting levels. In addition, the peformance specification should limit the competition to vehicles that are in the desired range of operating characteristics and configurations (e.g., seating capacity).

Small Bus Market

Small buses (or vehicles that may be converted to small buses) are produced by every major automotive manufacturer, and by a large number of independent bus builders. Most manufacturers either assemble from stock components, build bodies on truck chassis, or modify light trucks or vans.

With few exceptions, the small buses on the market are not designed and engineered from the ground up for use in urban transit service. Instead these vehicles or their key components are designed for other basic uses, such as light or medium trucks, recreational vehicles, and vans. Their suitability as small transit buses depends on selection of an appropriate basic vehicle or chassis, the options and components included (such as brakes and transmissions), and design of the added bodies or conversions.

The market for small buses is such that they are assembled to order, and therefore, the configuration is only limited by the availability of compatible components within the size- and load-range of the basic vehicle. With such flexibility, it is usually possible for the manufacturer to assemble a unit which will perform well under a specified set of conditions. LCC encourages the manufacturer to do just that.

Data Requirements

A major difficulty in performing the LCC analysis is acquiring and applying the extensive data that must be available for each candidate vehicle. These data must be consistent and complete so that competing vehicles can be compared on an equal basis. If vehicles are tested on site and in the intended operating environment, then there will be little question regarding applicability of the operating data. But, it may be impossible or undesirable to restrict bidding only to prospective vendors whose vehicles have undergone on-site testing. Therefore, the purchaser should be prepared to evaluate data from other sources and, if the data are of acceptable quality, adjust and apply these data to the anticipated experience on site.

Procurement Procedures

Procurement of small buses based on lowest life-cycle cost has four basic steps that must be followed in order to achieve the objective of selecting the most economical vehicle to perform the required service.

These basic steps are:

- Development of a performance specification;
- Solicitation of proposals to furnish vehicles conforming to the specification;
- Acquisition of appropriate data on performance and operating costs of each vehicle under consideration; and
- Computation of total life-cycle cost for use as a primary selection criterion.

Each of these steps is subject to many variations arising from differences in local practices, facilities, conditions, and availability of appropriate operating data.

A typical small bus procurement using life-cycle costing (Figure 1.) might start with development of a performance specification and an RFP or IFB to supply a limited number of test vehicles. These test vehicles would be operated in regular service long enough to determine performance and operating costs. Following the test period, the performance specification would be reviewed, and probably amended. Proposals would then be solicited for vehicles, with the notification that selection will be based on lowest life-cycle cost. When the proposals are received, each proposed vehicle would be compared with performance requirements and the availability of costing data would be determined. Data derived from on-site tests, other tests, and experience of those who have operated the same or a very similar vehicle would be acceptable. Life-cycle costs would then be calculated for each of the qualifying vehicles. This would be followed by selection of the vehicle with lowest life-cycle cost and award of the contract.

Under this procedure, it is not essential that every operator conduct tests of vehicles, nor is it considered desirable in all cases. Availability of extensive data on a particular vehicle, lack of appropriate facilities for controlled testing, and timing considerations are possible reasons for omitting tests of some vehicles or for omitting the vehicle testing phase altogether. Speculative data, however, must be excluded. Nor may opinion, unsupported by facts, play a role in this procedure.

The following chapters deal with four distinct aspects of LCC procurement as it may be applied to small transit buses. These are:

- Procurement of test vehicles;
- Conduct of testing;
- Procurement based on LCC analyses; and
- Analysis of life-cycle cost.

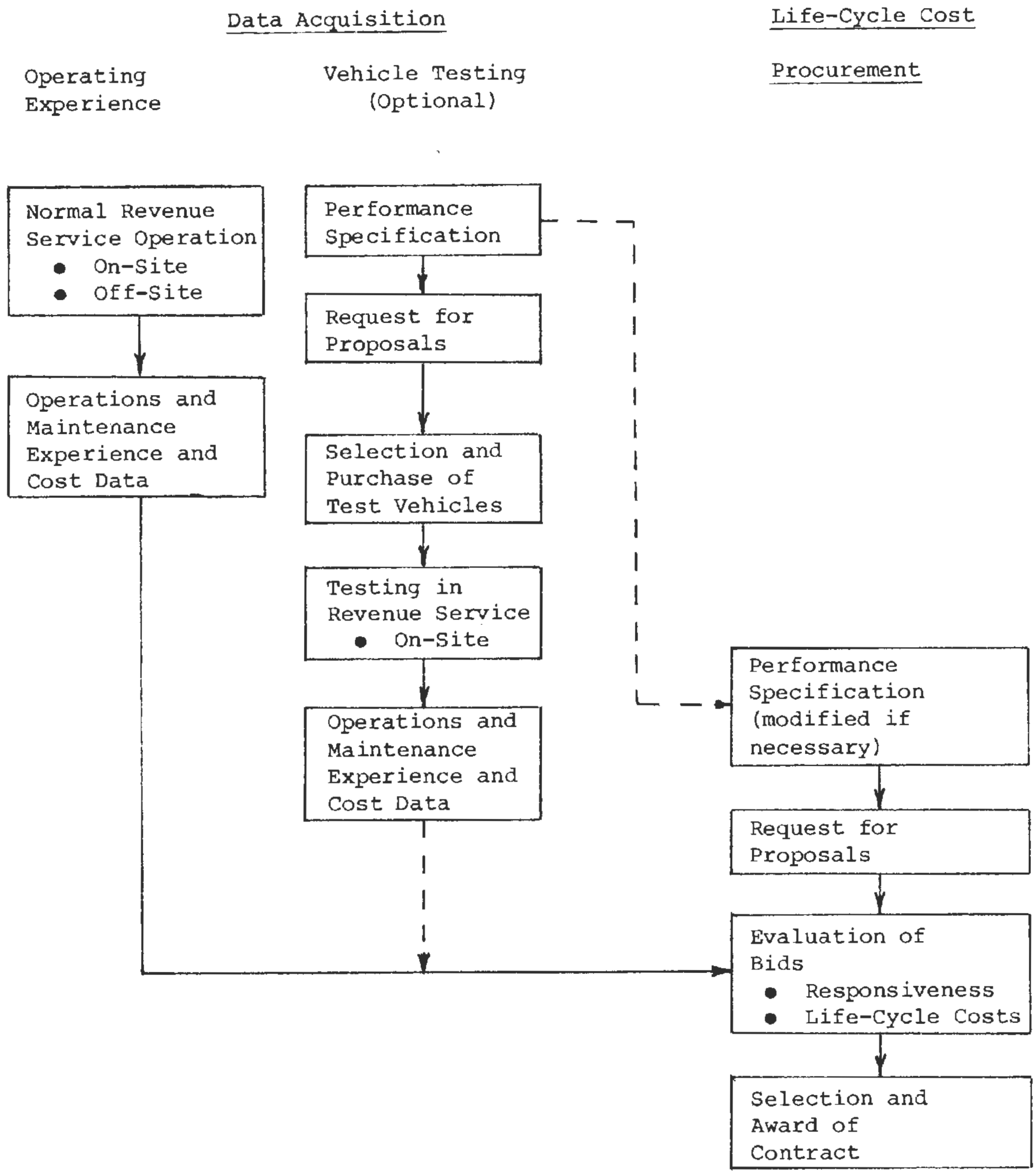

FIGURE 1. Life-Cycle Cost Procurement Process

II. TEST VEHICLE PROCUREMENT

Test vehicles are used to gain information on operating costs in the service environment. Data gathered during the test period will be used later in a procurement based on life-cycle costing. However, the procurement of vehicles for LCC testing is a directed procurement process similar to a search for sources. Small numbers of apparently acceptable vehicles are purchased from one or more manufacturers. The purchases are subject to conditions that are established in the request for proposals. These conditions limit the obligation of the operator, consistent with the operator's ability to support test operations. These conditions should also set forth valid criteria for selecting test buses. In general, initial price of the vehicle should not influence the selection of test vehicles, because a higher priced bus may have lower operating costs and, hence, a low life-cycle cost.

Cooperation between Buyer and Manufacturer

Acquisition of small buses for testing purposes places an obligation on both the buyer/operator and the manufacturer/seller. The operator incurs an obligation to operate the vehicle in a fair and unbiased manner and to keep complete records relating to operating conditions and experience, as well as costs of maintaining and operating the vehicle. The manufacturer incurs an obligation to provide representative production vehicles for the test, and to furnish certain elements of support during the test period. The test period should be regarded by both parties as a time for cooperation and frequent technical consultation, with the objective of qualifying the vehicles under test for future life-cycle cost procurements on the most favorable basis. To facilitate cooperation, test records should be kept up to date and should be open to inspection by representatives of the manufacturer. Open records will eliminate a possible major source of protests during future LCC procurements. More importantly, open records provide a basis for adjustment of maintenance and operating procedures and for cost-saving product improvements.

Product Improvement Based on Vehicle Testing

Product improvement, particularly as it affects quality of service and operating cost, is an important element of the LCC procurement and vehicle testing processes. Redesign of grab rails to improve accessibility and passenger well-being, replacement of an alternator with a heavier duty model, or replacement of the driver seat with a model designed to limit fatigue, are examples of product improvements that can result from vehicle testing. The feedback from operators on design features and components which increase costs, or otherwise cause difficulties, provides the manufacturer with a basis for designing a more cost-effective vehicle. Furthermore, the testing process, if properly conducted and reported, provides the operator with the basis for adjusting operating costs of improved vehicles.

TEST VEHICLE PERFORMANCE SPECIFICATIONS

The performance specification for small buses to be used for testing purposes is a basic part of the procurement process. This specification serves to limit the procurement to vehicles that have suitable operating characteristics, design features, and capacity for performance in the test environment. The performance specification should not cite detailed engineering requirements for the vehicles, as this could eliminate candidate vehicles with unusual or innovative design.

The performance specification establishes the standard for technical responsiveness of bids and protects the operator from incurring an obligation to test vehicles that are unsuited to the service in which they will operate. Testing of unsuitable vehicles has several obvious disadvantages from the viewpoints of both the operator and the manufacturer. The operator incurs costs associated with testing and subsequent disposition of the vehicles. In addition, depending on the nature of the inadequacies, the operator may find it difficult to maintain the desired level of transit service or to accumulate sufficient mileage on the test vehicles. Furthermore, if there are limited opportunities for testing, the operator would be denied the test data on another candidate vehicle. The manufacturer's primary concern is that, in an unsuitable environment, the vehicles may perform poorly, leading to adverse publicity and various other problems. Also, the manufacturer may incur substantial costs in support of vehicles that require excessive maintenance work because they are poorly adapted to the operating environment.

The performance specification should clearly state the requirements for:

- Capacity of the vehicle, seated and crush-loaded;
- Passenger accessibility features, such as maximum floor height and step height, door width, aisle width, and hand holds;
- Ride comfort;
- Acceptable noise levels, both interior and exterior;
- Heating, ventilating and air conditioning;
- Emission control limits;
- Route and destination signs;
- Fare box and radio accommodations;
- Special auxiliary equipment (such as wheelchair lifts), either installed or to be accommodated;
- Cosmetic features (such as exterior finish);
- Optional upholstery, carpeting and similar features; and

- Equipment options (such as automatic transmissions or diesel engines) where there is an operational justification for requiring such options.

In addition, the operating environment must be defined to assist the bidder in selecting a vehicle and components with appropriate characteristics. The description of the operating environment may be given in terms of terrain, pavement types and conditions, traffic, normal operating profile (speed, stop frequency, acceleration and deceleration) during typical revenue service operation, and climatic conditions.

The performance specification is intended to admit safe and efficient vehicles that are functionally suited to the particular application. Arbitrary requirements and restrictions should be avoided unless substantive reasons exist. For example, diesel engines might be specified if existing bus servicing facilities lacked storage and pumps for any other fuel. As an alternative, the property might indicate a preference for diesel engines without making them a requirement. The property could state that, because only diesel fueling facilities are readily available, gasoline fueled vehicles would incur a time and cost penalty to fuel at another location (or an amortization cost for providing gasoline storage tanks and pumps).

Performance requirements, such as seating capacity, speed and acceleration, limit the number of productivity variables that must be considered in later LCC evaluations. By specifying capacity, acceleration and speed ranges (or minimums) the vehicle productivity variables are reduced to those relating to reliability and downtime. This simplifies LCC analysis by eliminating driver labor from the calculations, because driver labor (and related categories of costs) will be the same for all vehicles meeting the performance specification.

REQUEST FOR PROPOSALS (RFP)

The request for proposals to furnish small buses for testing purposes should include the following clauses that would be omitted if a conventional low-bid purchasing action were planned.

Statement of Purpose

A definite statement is required in the RFP that describes the intended use of the vehicles and the implications of such use. It should be understood that future purchases of similar vehicles will be decided on the basis of low life-cycle costs. Vehicles purchased under the current procurement action will be operated in revenue service while data required for the analysis of life-cycle costs are collected. Successful completion of this testing phase will establish the data base necessary for evaluation of life-cycle costs during subsequent procurements.

It should be made clear whether subsequent procurement will be open to bidders who did not participate in the test. If bidders who did not participate in the test are to be admitted to later LCC procurements, an acceptable data base must be available for the LCC analysis (see the discussion of Data Sources in Chapter V). The assurance that acceptable data for a particular bus will be available from another source at the time of such LCC procurement may be a basis for eliminating that bus from the test vehicle purchase when the capacity for conducting tests is limited.

Conditions Governing the Procurement

Several constraints on the conduct of tests in the transit property must be translated into conditions governing the procurement action and the purchaser's obligations. The purchase must not exceed the number of vehicles that the operator needs at the time for revenue service; otherwise, the individual test vehicles will not accumulate sufficient mileage during the test period. Similarly, if maintenance facilities or personnel are limited, then the added burden of test vehicles should be limited to a number that can be properly maintained, taking into account unfamiliarity with the test vehicles and the need for extensive data collection.

The purchases from any one source should be limited to the number of vehicles required for an adequate test (see Chapter III), so that as many different vehicles as practicable may be tested and the number of vehicles to be disposed of in the event of unsatisfactory performance is minimized. This number is determined by the requirement for statistically reliable operating data. The purchaser should retain the option to acquire more test vehicles of a given model if there are fewer responsive bidders than permitted by the limit on total number of test vehicles purchased.

The purchaser should require the test vehicle suppliers to assume certain obligations and responsibilities during the test program. These obligations relate to technical and logistical support required during the tests.

The supplier should agree to furnish bona fide production vehicles for the testing program. In other words, the test vehicles should be assembled with standard production components, using the same production management and quality control procedures that would be in effect for a normal low-bid procurement or for a later LCC procurement. Use of custom assembled prototype, or specially tuned and adjusted, vehicles during testing would tend to bias the results and give such vehicles an unfair advantage in subsequent LCC procurements. In the event that the manufacturer has not yet entered into production of the tendered vehicle, this condition may be considered negotiable. However, the more equitable solution is to disqualify the bidder, especially if the operator anticipates that additional tests will be conducted at a later time, after the disqualified vehicle enters production. The decision on acceptance of prototype vehicles for testing will depend, at least in part, on the transit operator's commitment to encouraging innovation and the apparent advantages of new features of the proposed vehicles. If the proposed preproduction vehicles are simply a new model conforming to conventional design practice, there is little justification for testing a prototype.

Parts Supply

Parts supply frequently presents problems for operators of small fleets of like vehicles. Transit shops are often limited in parts storage space and unable to justify large investments in parts for a very few vehicles. This problem is usually not serious if a distributor or parts depot stocking all commonly required components is located nearby. If such parts supplies do not exist, an agreement for parts support should be a condition of the purchase contract. Parts supply for three or four test vehicles requires a level of support different from that required for a larger fleet purchase, for which the operator would expect to maintain a much more extensive stock of parts. The manufacturer should be advised that if test vehicles are out of service due to part delays or unavailability, they may incur a penalty in the productivity or fleet requirement computation of an LCC analysis.

Therefore, it is necessary to have a clear understanding between buyer and seller regarding parts supply. This must include procedures and cost responsiblility for expediting delivery of parts not stocked at the test site, types and levels of parts stocks to be maintained by the operator, and any adjustments allowed to downtime incurred because of delay in obtaining repair parts. Also, the seller should be advised that the use of custom fabricated or non-production components may result in severe downtime penalties if a test vehicle is out of service for an extended period because of unavailability of such parts. But, if unavailability of parts is beyond the supplier's control (e.g., because of a strike), downtime adjustments should be allowed.

Scheduled Servicing Standards

The manufacturer should specify standards and schedules for inspections, preventive maintenance, lubrication and servicing of the test vehicles. The optimum set of standards and schedules should result in the lowest total cost for unanticipated failures, repair work, and preventive maintenance checks and services. If operating experience indicates that the maintenance schedule should be adjusted, adjustment should be by mutual agreement. In the event that the manufacturer does not have an appropriate schedule for preventive maintenance (e.g., if the bus is contructed on a multipurpose truck chassis) one should be negotiated with the buyer's maintenance staff.

Open Test

It should be a stated condition of the procurement that all data will be processed and evaluated at regular intervals (monthly or quarterly), and that the data will be made available for examination and discussion by interested parties. This clause relates particularly to the vehicle suppliers, who should be encouraged to review the results on their vehicles and on competitors' vehicles, to raise any procedural questions they may have, and to make recommendations regarding servicing, trouble-shooting, and repairing of their vehicles.

Technical Consultation

The suppliers should expect to have their technical representatives visit the test site at regular intervals, to review the records and experience and to resolve problems. These visits will give the manufacturer an opportunity to advise on correct maintenance procedures and to detect areas where the performance of their products can be improved. From the operator's point of view, the visits offer assurance that the tests are being conducted fairly. But more importantly, they provide opportunities to correct problems that might cause a potential winner to appear unfavorably. Once testing has started, any changes in procedures must be agreed to by both operator and manufacturer of the affected vehicle and made a part of the open record of the tests. This technical consultation should be regarded as a friendly and mutually beneficial procedure.

Product Improvements

During the vehicle tests, problems should be expected to arise that can be alleviated by modification of the vehicle or substitution of components. When such modifications will improve the performance and cost experience of the test units, it is advantageous to both the operator and the manufacturer to make the change immediately. Otherwise, the operator incurs the costs of maintenance and also the inconveniences associated with poor performance. By permitting modifications, the benefits accrue immediately from the reduced costs and the operator also gains experience with a modification that may be incorporated in future purchases. The manufacturer, on the other hand, wants to present the vehicle in the most favorable light in order to promote future sales. The operator must determine if it is appropriate to adjust pre-modification cost data to be consistent with improved experience following the modification.

The operator must exercise configuration control and protect the validity of the test data. Therefore, the RFP should define steps for gaining approval of modifications and for determining who will be responsible for their cost. Assignment of responsibility for cost and execution of approved modifications should be considered an essential element of the approval negotiations. Downtime associated with installation of an agreed-upon modification should be excluded from the calculations to determine vehicle availability.

EVALUATION AND SELECTION

The evaluation process for test-vehicle bids includes determination of responsiveness to the legal and performance requirements of the RFP and exercise of judgment to determine the vehicles for which obtaining test data would be most advantageous. As a general rule, vehicles should be selected that are expected to be strong contenders in a future LCC procurement.

The issue of reponsiveness usually will not be resolved on a "black and white" basis. Because of the diverse nature of the small bus market, most bidders probably will propose exceptions and compromises to comply with the performance specification. Each of these cases must be evaluated on its merit, taking into account the importance to the operator of a particular requirement (i.e., essential, very desirable, or simply preferred) and whether other bidders are in compliance. One or two exceptions will generally be acceptable, but several minor exceptions or an exception to a major (or essential) requirement will usually be cause for rejection. Also, consideration may be given to exceptions in production vehicles proposed for test purposes, if the bidder certifies that such exceptions would be eliminated in a major buy, and if the exception would not prejudice the conduct of tests.

While the test-program-related requirements of the RFP should be regarded as secondary aspects of the evaluation and selection process, difficulty in negotiating mutually acceptable terms for conduct of the tests may be indicative of fundamental problems. For example, a serious parts supply problem, with the probability of delays in delivery of several days when a part must be back-ordered, should be assessed for implications of inadequate parts supply for a larger fleet of vehicles. Similarly, unwillingness of the manufacturer to recommend a preventive maintenance services schedule may indicate a lack of commitment to supportive technical participation in the tests.

Availability of acceptable test data from another source should be considered a valid basis for excluding an otherwise acceptable offer when selecting the test vehicles. For example, if another transit operator is already testing or regularly operating a particular vehicle, there may be little reason for running additional tests. This is true particularly when there are qualified candidates that cannot be accommodated in the test program.

In summary, the evaluation should consider the following points in arriving at a final selection of test vehicles:

- Legal responsiveness of the proposal;
- Compliance with the performance specification;
- Availability of suitable operating data on particular vehicles;
- Acceptability and implications of terms for conduct of tests; and
- Feasible number of test vehicles.

The number of test vehicles selected will depend primarily on the operator's ability to support the testing program and on the number of vehicles that can be placed in service. In the event that there are fewer acceptable offers than the operator's limit, there are two principal alternatives. The operator may either increase the number of vehicles in each test vehicle sample, or further limit the size of the test and, if necessary for service reasons, acquire additional vehicles for regular non-test service.

III. VEHICLE TESTING

When data suitable for LCC analyses are not available from the operators of small buses, such data can be obtained by testing selected buses in the operating environment. The following guidelines describe the conduct of tests and propose criteria for assessment of data from other sources. On-site testing is not a prerequisite for conducting an LCC procurement, but it does assure the operator of control over test conditions and data collection activities, and eliminates doubts regarding the applicability of the results.

TEST VEHICLE SAMPLE SIZE

The sample of operating data to be collected during vehicle testing must be of sufficient size to insure statistical reliability and to permit detection of anomalies and inconsistencies. The sample size consists of two elements: number of sample vehicles and length of the test period. Test period in turn may be measured in two ways: mileage and time duration. In practice, the sample size should also be kept to the practical minimum to avoid unnecessary expenses or interference with normal operations, and to insure the timely availability of results.

Number of Test Vehicles

Experience in maintaining fleets of transit buses reveals that individual coaches have maintenance histories similar to other coaches of the same model and age. For example, at one property maintenance records for four small and four conventional transit coaches, from time of purchase to approximately 18 months of service, showed consistent results between vehicles and clearly defined, moderately increasing cost trends.(13) Maintenance labor hours per 5,000 miles of operation for these vehicles ranged from zero to approximately triple the average hours, with a standard deviation of the same order of magnitude as the average hours of maintenance.

Differences between vehicles of the same type were small, not exceeding 15 percent of the average maintenance hours, except where unusual occurrences had taken place. By excluding these occurrences (e.g., shakedown and seasonal problems) from the analysis, the differences between vehicles could be reduced to below 10 percent. The small buses had approximately double the average maintenance labor costs of the conventional coaches for the particular samples used. But, the same general patterns and relationships were observed in both sets of data.

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[13] Based on an analysis of work orders for two types of vehicles, tabulated by a medium-sized transit property in the Great Lakes region.

Because maintenance activities include predictable, periodic work (e.g., servicing, brake relining), seasonal activity (e.g., air conditioner servicing, cold start problems), and random events (e.g., electrical failures, fluid leaks), these results are as consistent as may be expected. Furthermore, records of maintenance activity for any three vehicles of the same type were representative of a statistical population in which the experience with the fourth vehicle could have occurred. Thus, consistent results are obtained with a sample of no more than three vehicles, and the accuracy of test results will be only slightly improved by adding to the number of test vehicles of a given type.

The argument for a minimum of three vehicles is based on two considerations. If, for some reason, one of the test vehicles develops a maintenance history that is significantly different from the normal expectation, then the other two vehicles will provide a baseline for comparison. This comparison will serve to identify the abnormal experience and the causes of differences. Also, if one of the test vehicles is severely damaged in an accident or otherwise put out of service for an extended period, there will still be two test vehicles for which complete data are obtainable.

Length of Test

Test length is the period of time available for collecting a reliable body of data on operation of the test vehicles. While it may be possible to run the testing program longer than the recommended period, this does not appear to proportionally improve the quality of the data. Test time may be reduced by operating the test vehicles more intensively during the test period, provided that at least a year's data are collected. But, if intensive operation is used to shorten the test period, the data will require adjustment to compensate for reduced maintenance related to age and exposure (e.g., corrosion and deterioration of seals and rubber components).

TEST ENVIRONMENT

Data collected during the testing phase will be used in the evaluation leading to a later contract award to that manufacturer having vehicles with the lowest life cycle cost. Therefore, the tests should be performed in an environment that will allow for objective comparison.

Operations

Operations at the test site must be flexible enough to provide an equivalent operating environment for all test vehicles. All vehicles should be operated under comparable circumstances — routes, conditions, hours of operation and numbers of miles. Comparability can be assured by rotating the vehicles on a regular basis to each of the appropriate work blocks. Vehicle work assignments should be made in advance and periodic adjustments should be made to correct for unscheduled maintenance downtime.

Maintenance procedures for the test vehicles should be flexible enough to distinguish between deferrable and urgently required maintenance. Scheduled maintenance should be based on both the recommendations made by the manufacturers and on the preventive maintenance normally performed on vehicles in similar service. Manufacturers' scheduled maintenance must be adhered to unless changes have been agreed to by the manufacturer. Additional preventive maintenance procedures should be applied equally to all test vehicles.

Facilities and Personnel

The transit property personnel who participate in the day to day conduct of the vehicle tests exert a strong and pervasive influence on the test results. For many of these employees, the tests impose requirements beyond those normally associated with their positions. Mechanics and servicemen may be required to work with several different types of vehicles and to record more detailed data on work performed. Drivers, also, will be working with new and different vehicles and will be expected to report on performance, and on passenger comments or difficulties. Supervisory personnel will be responsible for overview of employee performance of extraordinary tasks related to the testing, recording of observations on the nature and causes of problems, and control of assignments of test vehicles for operation, servicing and repairs.

Employees associated with the test should be carefully screened for technical qualifications, experience, and attitude. It is particularly important that employees with a negative attitude, towards either the test program or any particular vehicle model being tested, be remotivated or assigned to other work so that test results will not be biased or open to question of bias.

The selected test project staff must be briefed on the purpose of the tests and on the test program. In addition, each of these employees should receive special training for work to be performed on test vehicles and for any test-related tasks, such as recording and control of test data. The objective of the training program is to prepare drivers, servicemen, and repairmen to perform their work on the test vehicles with the same level of competence and familiarity they bring to the rest of the fleet.

The facilities of the test site must be allocated to the test vehicles in an equitable fashion. For example, some test vehicles should not be stored indoors while others are kept outdoors. It is desirable to reserve certain portions of the site's facilities for test vehicle maintenance and storage, with all personnel aware that controlled test procedures must be observed in such areas. These measures will facilitate detection of problems, such as fluid leaks, and help to maintain uniform conditions for different model test vehicles.

Management

The vehicle testing program will have major effects on the principal operating and support functions in the transit property. The program will need high-level management support and cooperation in order to run smoothly and effectively. Both transportation and maintenance departments have key roles in the conduct of the test. Purchasing, personnel, accounting and data processing (if it is a separate group) will have major responsibilities in support of the tests. Also, activities such as planning and marketing should consider the implications of their programs on the course of the tests.

To be effective, the test program manager will require the authority to coordinate diverse activities including operations and maintenance functions and supporting services. He must be able to deal with personnel at all levels in the transit property and to represent the property in an official capacity when conducting test-related business with outsiders (e.g., manufacturers' representatives). Apart from the obvious technical and professional qualifications, the test program manager should be an individual who has the confidence of key middle managers and direct access to the top management in the property.

CONDUCT OF TESTS

Testing should be based on procedures that will insure complete, accurate, and unbiased test results, within reasonable limits of costs and time. The testing procedures should be sufficiently flexible to permit adjustments and modifications.

Manufacturers of the test vehicles must be aware of the intended use of the vehicles and of the ground rules for conduct of the tests. Changes in test procedures and modifications of test vehicles should be decided on with the manufacturers.

Modifications During Tests

It is desirable to allow competing manufacturers to make modifications to their vehicles during the test phase. These modifications may include alterations to the vehicle structure (e.g., strenghthening of members, improved accessibility) or substitution of components that the manufacturer believes will reduce operating costs or improve reliability.

The operator and the manufacturer should agree on any modification prior to application. The contract between the operator and the manufacturer must include provisions for resolving disputes that arise over modification approvals. The modification may take the form of changes in actual components or in engineering specifications. All modifications must be disclosed to the other competing manufacturers. Data collected prior to modification of the vehicles should be adjusted, provided that a significant change in performance or costs results from the modification.

Test Data

The test data include the entire body of information describing the conduct of the tests, vehicle operations, servicing and repair required, and costs incurred. In most instances, basic data of this type are being regularly recorded as part of the transit property management and control functions. However, the testing program will probably require additional detail, more extensive processing, and retention of the data in a permanent form for use in the life-cycle cost analysis. Source documents will include many of the records and work sheets that normally support the transportation and maintenance functions (e.g., dispatchers' check out and check in sheets, communication logs, back order reports, servicing records, inspection forms, maintenance work orders, accident reports and mileage logs) and may be supplemented by special test forms, such as driver and repairman interview reports, and passenger survey forms.

The objective of the data management effort should be to maintain a complete record of all aspects of vehicle performance during the test period. Basic costs and performance data should be reviewed and summarized at regular intervals (weekly or more often) for use in managing the test (e.g., equitable treatment of vehicles, early detection of problems). Copies or abstracts of source documents, such as work orders and bad order slips, should be retained in individual vehicle history files, so that confirmation of details can be at hand during the subsequent analyses.

MAINTENANCE DATA

Servicing and maintenance data are the bases for the calculation of the specific operating costs of small buses (i.e., operator wages are usually the same for all vehicle models). Therefore, the procedures for collecting these data are crucial to the testing program. These data are used for scheduling of inspections and similar activities, as well as for mechanical performance measures and costs. The basic data elements include:

- Mileage operated;
- Fuel, oil and coolant consumed;
- Labor hours and costs for maintenance and repair; and
- Cost of parts and materials.

The maintenance and repair costs should be identified by major reasons for work and by subsystems of the vehicle, in sufficient detail to permit analysis and comparison of vehicle maintenance experience. Table 1 contains a typical list of categories for recording maintenance labor and parts costs. This list may be expanded to include categories causing particular concern (e.g., wheelchair lifts, compressed air, radio) or to yield a more detailed breakdown (e.g., electric might become generator, battery, starter, lighting, and accessory power).

Several options are available in selecting a system for the collection of test data. Possibilities include: an existing maintenance records system if it meets the requirements of the test program; the manual system described in these guidelines; and the Service, Inventory and Maintenance System (SIMS) or a similar automated system. It is at the discretion of the operator to use that system which is most effective for recording the LCC data.

Table 1. Maintenance Cost Categories

Work Reasons	Vehicle Subsystems	
• Inspection	• Front Axle	• Engine
• Bad Order	• Rear Axle	• Transmission
• Accident	• Brakes	• Wheels/Tires
• Vandalism	• Clutch	• Body
	• Cooling	• Air Conditioning
	• Electric	• Miscellaneous

Existing Data Collection Systems

The transit property will usually prefer to use its own system for data collection because of familiarity with the procedures and because the system is already installed and operating. Whether the system is manual or computerized, it should:

- Collect and record for each vehicle
  - Vehicle mileage travelled,
  - Service mileage for sub-assembly categories,
  - Fuel, oil and coolant consumed,
  - Labor hours and costs for repair, and
  - Cost of parts and sub-assemblies that were replaced during maintenance;
- Provide a description and causes of repair work;
- Indicate sub-assemblies replaced;
- Identify personnel who performed maintenance repair and service;
- Indicate labor rates for repair and service personnel; and
- Provide a complete performance and maintenance history of each vehicle.

These data are necessary for evaluating and comparing different vehicles. If the property's record system does not meet these requirements, it should be modified or another system should be used.

Manual LCC Data Collection System

The following manual system, designed specially for LCC data collection needs, provides an example that the operator may adapt for use in a particular test. This system (See Appendix A) is based on forms used by transit operators for manually-recorded maintenance and service data and consists of a series of related forms. The system has two basic sections: The Journal Section, and the Vehicle Operating and Maintenance Cost Report Section.

The Journal Section contains three tally sheets:

- Vehicle-Miles Journal;
- Vehicle Servicing Performed Journal; and
- Vehicle Repair, Materials and Labor Journal.

Vehicle-Miles Journal (Figure A-1) is filled in each day, recording the total mileage on the odometer and the daily miles travelled for each bus.

Vehicle Servicing Performed Journal (Figure A-2) is filled in each day, with the daily fuel, oil and coolant added to each bus. Depending on servicing practices, the operator may include brake and transmission fluid on this journal. The sheet is filled in at the time the commodities are added to the vehicle. The fuel added is recorded to the nearest tenth of a gallon, and the oil and coolant added are recorded to the nearest quart.

A Vehicle Repair Materials and Labor Journal (Figure A-3) is filled in for each vehicle at the time each repair or maintenance activity is performed. There should be one of these sheets for each repair order. The sheet is initiated by the foreman or leadman assigning the work and completed by the mechanic performing the work. Necessary information includes vehicle repair date, vehicle number, total mileage to date, mechanic's identity number, group and unit worked on (e.g., body, front axle), elapsed time, repair cause and description, parts item description, house inventory number, quantity and unit. The sheet can be inserted into a time clock to record the in and out times.

The data from these journals are summarized in the Vehicle Operating and Maintenance Cost Report Section. Four separate records comprise this section:

- Vehicle Assignment and Miles Record;
- Commodity Cost Record;
- Maintenance Labor Record; and
- Material Issue and Return-to-Stores Record.

A Vehicle Assignment and Miles Record (Figure A-4) is maintained for each bus. This record allows the operator to compile the total vehicle-miles to date and total miles travelled for a period. The original source of data for this record is the Vehicle-Miles Journal. The transfer is made from the appropriate line and column in the journal to the individual records for each vehicle.

For each vehicle being tested, a separate Commodity Cost Record (Figure A-5) is compiled. The primary source of data for this record is the Vehicle Servicing Performed Journal. The "constants date" in this record refers to the date that fuel, oil and coolant were purchased at the indicated price. When a change of price occurs in any one of the listed commodities, the constants date changes accordingly. After the prices and quantities have been recorded, the commodity costs are computed by multiplying the amount of commodity added by the appropriate price. When a designated period has been completed, the commodity costs are computed and totaled for each commodity. The three commodity categories are then added to provide a total period cost and a total operating cost to date.

The remaining two records in this section allow the operator to compute maintenance costs. The Maintenance Labor Record (Figure A-6) contains total maintenance labor costs, which are calculated by multiplying elapsed time, furnished in the Vehicle Repair, Materials and Labor Journal, by the hourly pay rate. The hourly pay rate is determined by the job classification of the employee performing the work. (The employee's personnel number is used as a cross-reference to an hourly pay rate list).

The Material Issue and Return-to-Stores Record (Figure A-7) itemizes maintenance material usage and costs. Usage data are transferred from the Vehicle Repair, Materials and Labor Journal. The recorder must obtain unit prices from parts inventory records. Material costs are calculated by multiplying the quantity used by the unit price.

Service, Inventory and Maintenance System

To collect LCC data, the property may choose to use the Service, Inventory and Maintenance System (SIMS), a maintenance management system developed specifically for diesel transit buses. SIMS is a computer-based information system that can provide the operator with all data needed to conduct an LCC evaluation. SIMS also may be used to assist in scheduling preventive maintenance services and inspections. (Additional information on SIMS is available from the UMTA Office of Transit Management.)

SIMS consists of three interrelated modules:

- Inventory Module;
- Repair Cost Module; and
- Service/Unit Change Module.

By processing parts issue and receipt transactions, the Inventory Module provides status records on each item in the controlled inventory. This status information is used by management in recording, purchase order monitoring, and financial control. Use of repair parts is summarized in the Issue Transaction Report and transferred to the Repair Cost Module for use in the calculation of total repair costs.

All maintenance labor transactions are recorded in the Repair Cost Module in terms of both hours and costs. Labor costs, incurred in the repair and maintenance of a vehicle, are added to the materials cost for that vehicle (supplied by the Inventory Module) to report the total costs for repair and maintenance of that vehicle.

The third segment of SIMS, the Service/Unit Change Module, keeps an operating history of each vehicle. Input into this module includes:

- Fuel, oil and coolant consumed;
- Inspection performed (type, date and mileage);
- Component or unit changes; and
- Miles travelled.

Miles travelled, as well as fuel, oil and coolant added are recorded on a daily basis.

SUBJECTIVE TEST OBSERVATIONS

Throughout the conduct of the vehicle tests, one of the most important sources of information is the opinions and experiences of people who are exposed to the vehicles on a regular basis. The views and reactions of drivers, repairmen and passengers are particularly important in evaluating the vehicle performance. Drivers and repairmen participating in the test program should be advised, during their initial orientation and training, that they will be asked to report their reactions to the test vehicles at regular intervals (monthly or quarterly) during the test period. This procedure should help to motivate these employees and gain their support of the test program. Also, comments on the test vehicles should be encouraged from passengers.

A checklist should be provided on which drivers may rate visibility, performance, passenger comments, difficulties, and features which they find desirable or helpful. Mechanics should be asked to rate accessibility and repairability of major components and to report the nature and causes of recurring problems. Both drivers and mechanics should be encouraged to make suggestions for improvement of the vehicles and correction of deficiencies affecting performance.

Subjective test observations are one of the possible bases for modification of the performance specification for later procurements. Also, in some instances characteristics that result in critical comment may be defined for use as weighted objective criteria applied, in combination with LCC, in the bid evaluation process.

IV. PROCUREMENT BASED ON LIFE-CYCLE COSTING

The procurement of buses based on LCC should be open to all potential bidders who can meet the performance specification and provide verifiable operating cost experience. The LCC procurement action is subject to normal procurement regulations and reviews. The major differences are the method of evaluation of bids and the fact that award is based on low life-cycle cost instead of low initial purchase price. The computation of the life-cycle cost is described in Chapter V.

REQUEST FOR PROPOSALS

The Request for Proposals (RFP) package should contain all necessary forms and information to assist the potential bidder. This includes the invitation for bids, instructions to proposers, contract documents, required certifications, technical specifications, a description of the basis for award, and data analysis procedures.

The RFP should specify the basic number of vehicles required but should advise the prospective bidders that the actual number of vehicles purchased may depend on the productivity of the unit purchased. The RFP may also indicate a maximum expenditure, based on the availability of funds.

Specifications

As discussed in Chapter II, the performance specification is an important consideration in the life-cycle cost procurement process. If a performance specification was used earlier to procure test vehicles, the performance requirements or characteristics may be amended, modified or supplemented. These changes may result from a redefinition of the operator's needs, a change in original preference, or a deficiency in the description of a particular component or characteristic.

Special Clauses

The Request for Proposals should include several special clauses relating to the life-cycle costing aspects of the procurement. These clauses describe the basis of award, evaluation process, alternative data sources, and qualifications and procedures for the inclusion of product improvements claims. Examples of possible special clauses include:

- Basis for Award

  A contract shall be awarded to the responsive bidder whose vehicle is determined to have the most favorable score consisting of life-cycle costs and other objective criteria, appropriately weighted. Criteria, and their respective weights, for bid evaluation are....

Or, alternatively:

A contract shall be awarded to the responsive bidder whose vehicle is determined to have the lowest life-cycle cost as defined herein and subject to the qualifications and limitations stated herein. The life-cycle cost shall include the initial bid price of the vehicle, the costs of operating the vehicle during the period of use, and a credit for residual value (salvage) at the end of the period of use, and shall be adjusted to account for present worth of future expenditures, projected inflation, and the effects of unavailability due to failures and repairs. The life-cycle cost shall be determined by the contracting officer using the procedures described herein. In the event that the life-cycle cost comparison is inconclusive as defined in the Clause, Evaluation Process, the contract shall be awarded to the bidder whose vehicle is determined to have the lowest initial purchase price.

(Lowest initial purchase price is used here as an example, only. The alternative selection criterion may be any clearly defined value that can be readily determined for each of the competing vehicles.)

- Evaluation Process

The evaluation process shall consist of the determination of responsiveness to terms and conditions of the procurement, computation of an evaluation score consisting of the elements and weights specified in the following table....

Or, if the award is to be based primarily on LCC:

The evaluation process shall consist of the determination of reponsiveness to terms and conditions of the procurement, computattion and comparison of life-cycle costs, and, if necessary, according to the qualifications stated herein, the evaluation of bids based on alternative selection criteria. Alternative selection criteria shall be used to differentiate between those vehicles that have life-cycle cost estimates within two (2) percent of the lowest life-cycle cost.

(Two percent is used here as an example, only. The contracting authority should select an appropriate percentage to define the spread over which the life-cycle cost difference will be considered inconclusive for selection purposes.)

- Alternative Data Sources

  The contracting officer shall require data on performance and operating costs of proposed vehicles sufficient for the computation of life-cycle costs. Such data may have been acquired through test operation of the vehicles or prior operating experience with the same or a similar model vehicle either on site or on other transit properties. The contracting officer shall determine whether the data are of sufficient quality and completeness, describe sufficient operating experience, and are representative of conditions that are sufficiently similar to the intended service environment. The contracting officer reserves the right to reject the proposal to furnish any vehicle for which data, adequate for the computation of life-cycle costs, are not available.

- Product Improvements

  The manufacturer shall advise the contracting officer in writing of all modifications, specifications changes, and product improvements that will cause the performance or operating costs of the proposed vehicle to differ from that represented by the available performance and operating cost data. Modifications shall be described in sufficient detail to permit analysis by the contracting officer. The contracting officer reserves the right to accept, reject, or modify claims by the manufacturer, on the effect of modification on performance or operating cost of the vehicle.

UNCERTAINTY OF RESULTS

Life-cycle costing entails estimates of future repair frequency, future usage rates (e.g., miles per year), useful life, and rates for future inflation. Some of these factors, such as usage rates and inflation, are applied similarly to all vehicles being compared. But others, such as useful life,[14] repair frequency or fuel consumption rates, are estimated for each vehicle using similar operating experience data as a basis for the estimate. The accuracy of these estimates depends on how nearly the assumed future conditions (e.g., weather, price inflation, vehicle usage rates) approach the conditions that will actually prevail. Another factor is how representative the operating experience (e.g., vehicle test data), on which the estimates are based, is of the future performance of new vehicles. The estimates of useful life, condition and mileage at retirement, price of fuel and similar factors should be as realistic as the analyst can reasonably make them.

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[14] Useful life may be determined by the policy on replacement of vehicles in some instances. If vehicles are to be retired at a definite age, all vehicles would have the same life, unless experience or testing indicates that a vehicle would fail before scheduled replacement.

By treating each different vehicle in a manner consistent with the treatment of every other vehicle, some errors will tend to be compensating or self-cancelling when comparing life-cycle costs. For example, suppose the estimated future price of fuel is high by 10 percent but the miles of operation of two vehicles is the same (say 2,000 miles), and their fuel consumption rates are 8 miles per gallon and 8.5 miles per gallon. The net effect of the error in fuel price is only a 0.6% greater difference in costs of fuel, compared to the total cost of fuel, and a much smaller effect (about 0.1 or 0.2 percent), compared to total life-cycle cost.

In the example above, if the error were in the fuel consumption rate of one vehicle, then the full effect of a lower or higher rate would show up in the difference between total life-cycle cost. Suppose that instead of 8 miles per gallon, it was incorrectly assumed that the vehicle averaged only 7.8 m.p.g., (a 2.5 percent reduction). Fuel consumption (and fuel costs) for this vehicle would be over-estimated by nearly 2.6 percent and total life-cycle costs may be overstated by one percent or more. Such an error can easily occur if the operating cycle (i.e., grades, speed, stopping frequency, etc.), on which the estimate is based, differs from the proposed service (or the basis for estimates for the other vehicles).

Such uncertainty is present in all forecasts and does not detract from the fundamental value of projecting life-cycle costs. However, the uncertainty of the calculation of projected future costs does mean that small differences in the total life-cycle costs should not be regarded as conclusive evidence of real differences in value to the operator. Otherwise competitive vehicles, that are shown to have only small differences in life-cycle costs, should be regarded as essentially equal.

Proposal Evaluation Methods

Life-cycle cost may be used in proposal evaluation in several ways that avoid problems of uncertainty in the predicted future operating costs. The operator may define performance objectives to be achieved by each vehicle and assign points for exceeding each objective. For example, the minimum acceptable level of engine emissions is defined in the performance specification. Any vehicle exceeding this minimum criterion would be awarded points based on quantitative tests. Or, a maximum floor height for the bus may be specified and buses with lower floors (or lower effective boarding height) would receive points assigned on the basis of difference between effective height and the maximum allowable.

The points awarded for various features are then assigned weights and added to give a total score for each vehicle. Life-cycle cost (or points based on LCC) would have an assigned weight as would each of the designated performance criteria. Alternatively, the points awarded for exceeding the performance specification may be deducted from a base number (such as 100) and the resultant performance score multiplied by the LCC would give a performance-weighted life-cycle cost.

If LCC is to be used as the sole selection variable, then consideration should be given to a procedure that recognizes the possible ambiguity of very small differences in life-cycle costs and provides for alternative criteria when such differences occur. The limiting value for a significant difference in total life-cycle costs should be established by the contracting authority before issuance of the Request for Proposals. The number selected may be either a fixed dollar amount or a percentage of total life-cycle cost. For purposes of illustration in these guidelines, two percent of the lowest life-cycle cost has been used to define a zone for essentially equal life-cycle costs. Vehicles whose life-cycle costs fall within the zone should be considered equivalent with regard to life-cycle costs and an alternative procedure activated to select among such vehicles.

The use of two percent does not indicate that the contracting authority believes that the estimates of future costs are within two percent of the costs that will actually be incurred. Such costs may be in error by ten percent or more in the most carefully conducted analysis. However, use of consistent analytical procedures, and common factors and assumptions for the future, tends to minimize the relative error between life-cycle cost estimates for different candidate vehicles. Therefore, it is reasonable to assume that a comparatively small difference (such as two percent) in calculated life-cycle costs is indicative of superior cost performance for the vehicle with the lower life-cycle cost.

A value of two percent of lowest life-cycle cost (or an actual dollar amount of similar magnitude) is suggested based on evaluation of typical small bus operating data. The experienced analyst may wish to vary the limiting value based on such factors as the quality and applicability of the data used and the length of the future projection period.

Alternative Selection Criteria

The contracting officer should specify in advance the alternative selection criteria that will be applied in the event that total life-cycle costs are so nearly equal that the difference is not significant. The selected criterion should be based on readily available data and should be objectively related to the specified vehicles or the proposed operations. Possibilities include low initial purchase price (previously used as an example), reliability or availability (the ratio of time a vehicle is in or ready for service to total service schedule time), the seating capacity of the vehicles, and alternative computations of life-cycle costs (for example, life-cycle costs using undiscounted values for future expenditures and receipts). The alternative criterion should be applied only to those vehicles whose life-cycle costs are low enough to fall within the inconclusive range of the lowest life-cycle cost.

In a typical procurement, it is not anticipated that the limiting value for differences in life-cycle costs or the alternative selection criterion will have application. However, the inclusion of an alternative provides a safeguard for one of the contingencies which should be anticipated. Furthermore, the basic life-cycle costs determination should eliminate the majority of competitors in even a closely contested procurement.

ADMISSION OF TEST VEHICLES

The operator should reserve the right to select a limited number of test vehicles from among the bidders who were disqualified because of inadequate operating data, provided the operator has facilities for conducting vehicle tests. Selection of test vehicles should conform to the criteria described in Chapter II and should impose similar obligations on operator and manufacturer.

V. LIFE-CYCLE COSTING ANALYSIS

The analysis of life-cycle cost is a relatively simple computational process requiring the aggregation of large quantities of data and the exercise of sound judgment. In this chapter, sources and interpretation of data are discussed first, followed by consideration of the basic elements of the LCC equation. The final section deals with some exceptions that the analyst may have to consider.

DATA SOURCES

If tests have been conducted on-site and complete operating and cost data are available for each of the proposed buses being evaluated, the LCC analyses can proceed on a straightforward basis. However, this will rarely be the case. Even when tests have been conducted it may not have been practical to test all candidates, and responsive proposals may be received for models that were not considered for inclusion in the tests. In other cases, lack of time or suitable on-site facilities may have precluded the conduct of tests, in which case the analysis must depend entirely on data from other sources.

Test Data

Data obtained from on-site tests should present few problems, particularly if the steps to be covered in the LCC analyses were blocked out before the test-data collection system was designed. The analyst must keep in mind that test conditions are not identical to regular revenue service and that certain data may require adjustment. For example, vehicles may have been modified during the test period to eliminate an operating problem that was affecting costs or performance. In this instance, if the modification was successful and is included in the current proposal, the data collected prior to the modification should be adjusted to reflect the improvement. Similarly, a design feature or component that presented problems during the test may have been corrected in the current proposal. In such case, the analyst will not have the benefit of test data but must make an appropriate adjustment based on experience and the manufacturer's claims.

Transfer Data

The usual source of transit vehicle cost and performance data is the records of transit operators. Even when test data are available, the analyst should be aware of the experience of other operators and should check to be sure that the test data are consistent with such experience. Reasons for apparent inconsistencies should be determined and, if needed, appropriate adjustment to the data should be made. When test data are not available, experience with the types and models of buses being evaluated becomes the primary source of operating and cost data. Such data have two characteristics that may be an advantage over test data — they were collected under normal, rather than test, operating conditions and they usually include experience with a larger number of vehicles.

Ideally, data from other operations would have been collected in an identical service environment and in the same level of detail as on-site test data. Of course, this is never the case — routes, terrain, climate, operating policy, accounting and recordkeeping procedures, and a host of other factors will differ in a multitude of ways. The job of the analyst is to select sources of data that are sufficiently similar so that they can be used as is or, more likely, adjusted to reflect local conditions. It is not necessary that all data come from the same source. For example, frequency of brake relining may be determined from the experience at one location, while the estimate of labor hours required to perform the brake job may be based on data from another site. Also, when available, data from more than one site should be compared (after adjustment to represent generally similar conditions), and averaged if the results are similar. If dissimilar results are obtained, the analyst should attempt to determine the reasons for the difference before selecting a value for use in the LCC computation. Astute use of data yielding comparable values from more than one location can significantly increase the confidence in the final LCC value. However, finding suitable data is not always easy and it may be necessary to eliminate many possible sources because of environmental or other differences.

In handling off-site data, one of the most difficult problems is the adjustment of the data to make it fit local conditions. Generally, it is not acceptable simply to adjust costs for site differences by factoring labor rates and parts costs. Instead, the analyst must compare the two environments and then adjust various elements that contribute to total operating costs. For example, brake or transmission repairs may be adjusted on a basis related to terrain and stop frequency, while air-conditioning or engine-cooling data would be related to seasonal and climatic factors.

One effective technique for normalization of off-site experience is to compare the experience with another type of vehicle. If two locations operate similar model, conventional 35- or 40-foot transit coaches (as is often the case), a comparison of repair frequency for various vehicle subsystems should yield factors that can be applied to the small bus case. For example, if brake relining frequency for Coach A at Property X is 50,000 miles; for Coach A at Property Y it is 40,000 miles; and Property Y reports that Small Bus B requires brake relining at 30,000 miles; then Property X can reasonably assume that Small Bus B would require brake relining at about 37,500 miles (30,000 times 50,000/40,000). In making such adjustment the analyst should be reasonably confident that the components being compared are similar. For example, experience with automatic transmissions or diesel engines on coaches should not be assumed to be transferable to small buses with manual transmissions or spark-ignition engines. Similarly, caution is indicated if a component, such as the air conditioner, being supplied with the proposed small buses is a different model or from a different manufacturer than those installed on similar vehicles at the other location.

Manufacturer's Data

Data furnished by the manufacturer to support a proposal should be carefully analyzed and, if possible, verified by comparison with data from disinterested sources. When such verification is not possible (e.g., when no operator has comparable experience with a particular vehicle or design feature), the analyst should assess the reasonableness of the manufacturer's data and either accept or reject the data. The analyst should be particularly cautious about accepting data that tend to alter the basic results of the life-cycle cost analysis (as, for example, a claimed major improvement in fuel economy might do). Nevertheless, the manufacturer does have knowledge about the design and engineering of the vehicle that is a valuable resource, so such data must be considered and, in some cases, it will be the only data available.

Manufacturer's data are particularly important when newly designed modifications are incorporated in the proposed vehicles. In these cases, the analyst must decide on an appropriate adjustment to the earlier cost and operating experience. Modifications should be discussed with maintenance personnel and operators who are familiar with the vehicle to determine whether claimed benefits are reasonable. Also, the benefits should be relatable to the earlier cost experience (e.g., a doubling of brake life is unlikely to result in savings greater than half of the previous costs).

ANALYSIS

To calculate life-cycle costs of a vehicle, the analyst must project annual operating costs over the expected life, estimate the salvage value (or the residual value at the end of a specified period), and determine a productivity or availability ratio.(15) Operating costs and salvage value are then be adjusted for inflation and discounted to determine present worth of future expenditures and receipts. Finally, all costs including initial purchase price are aggregated and adjusted to account for vehicle availability, to determine the total life-cycle cost. When calculating life-cycle costs for comparative purposes (as in proposal evaluation), either the same expected life should be assumed for each model or an average annual cost should be used in the final comparison.

Each of the components of the total life-cycle cost is described in the following sections. Operating costs, which in the general case would include operator wages and similar charges, have been limited to those items which are variable in the small bus case. The variable operating costs are the vehicle maintenance costs (i.e., servicing and repairs of the

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[15] Productivity of a unit can be defined generally as the ability to perform work multiplied by the time available for work. In the small transit bus case the unit of work, passenger seating capacity, is usually specified as a constant leaving availability as the only variable.

vehicles) and commodity costs (i.e., fuel, oil and coolant consumed in the vehicle). These two categories of operating costs, maintenance and commodities, are described separately.

Maintenance Costs

The projected maintenance costs include all work attributable to the preventive, scheduled and nonscheduled maintenance of the vehicle (including the fair value of work done under warranty). Expenses include the costs of maintenance labor, units and parts replaced, and materials used. If different inflation factors are to be used for labor and parts, these costs should be separated — if not, they may be combined.

Maintenance costs are usually high during the first few thousand miles of service of a new vehicle because of early failures of defective components, "wear-in," and similar factors that affect costs. Costs then level off and begin a gradual increase that can be assumed to continue during the vehicle's useful life. The projection of future maintenance costs should follow this same pattern, based on average values from the test vehicles or experience at other locations, and related to the projected miles of operation during each year of the expected life. The actual calculation can be made by subtracting the cost of all test vehicle repairs identified as "wear-in" related, occurring during the first few thousand miles of operation, and averaging the remaining repair costs (on a per mile basis) in blocks of 5,000 or 10,000 miles. A trend line is then calculated (or determined graphically) using standard analytical techniques, and annual maintenance costs are projected for the mid-year mileage in each future year of operation. Finally, the average "wear-in" cost is added to the cost for the first year of operation. (This procedure accounts only for the increased use of labor and parts as the vehicle ages, not for the escalation of costs due to wage-rate and price increases, which is discussed in the section on inflation and discounting.)

If the test vehicles are under warranty for certain types of repair and maintenance, and if the same warranty provisions apply to the vehicles to be purchased, then the value of warranty work should be deducted from the projected maintenance costs during the warranty period. This deduction compensates for the cost of the warranty protection, which is presumed to be included in the intial price of the vehicles. Changes in warranty provisions will require the analyst to reassess maintenance work performed on the test vehicles, to determine which work would be covered under the new provisions.

Commodity Costs

Commodity costs include the costs of fuel, oil and coolant consumed by the vehicle during operation, Commodity costs may also include the cost of tires, if they are rented on a per mile basis (otherwise, it may be more practical to include tires in the maintenance costs). Similarly, the costs of labor for daily servicing, including fueling, cleaning, and washing, may be added to commodity costs but are usually included in maintenance costs.

costs such as tires and servicing labor may be omitted entirely from the calculation, if there is no basis for differentiating between these costs as applied to the different vehicles being compared. Moreover, if cost data developed at other sites are being used, particular care must be taken to be certain that such costs are handled consistently and equitably in the analysis.

Residual Value

The analyst must determine a salvage or residual value for each type of vehicle. For purposes of life-cycle costing, salvage value is defined as the fair market price for a vehicle at the end of the planned period of use (i.e., the useful life). Residual value would be used if the expected useful life exceeds the life assumed for the analysis and the transit property would retain the vehicle in service. Market price is dependent on the demand for vehicles of that type, the condition of individual vehicles, and the remaining economic life of the vehicle or the scrap value of the vehicle. For purposes of LCC analysis, recent sales prices and appraisals of similar equipment should be used as indicators of fair market value. Such data can be obtained directly from used equipment dealers and appraisal consultant. Ideally, current prices for used equipment of the same model and the same age as the vehicles being analyzed should be used. Where this is not possible, market prices should be estimated, based on the proportional change from initial price to used price (with due consideration for inflation).

Residual value of vehicles with a useful life significantly longer than the specified analytical period can be estimated by projecting annual service that would occur after the specified analysis period. Salvage value at the end of the useful life would be estimated as described above and increased by the initial cost less salvage value multiplied by the ratio of service mileage after the analytical period to total useful life service mileage. In some cases, a further adjustment may be made to account for increased operating costs during the residual life period.

All vehicles being compared in the life-cycle cost analyses will not have the same real useful life and, in some cases, the actual useful life may be difficult to estimate. For reasons of consistency in the analysis of life-cycle costs, the intended period of use for vehicles being procured should be specified in the Request for Proposals and held constant for all vehicles being analyzed. In actuality, the true useful service life of the different vehicles will probably not be the same. The inclusion of salvage or residual value in the life-cycle cost equation compensates for inequities resulting from differences in true useful life. For example, a vehicle with a practical life of six years will have a market value at the end of four years that represents the value to a second owner, whereas one with a practical life of only four years will be valued as scrap.

Vehicle Productivity

The number of vehicles required to perform a given service is made up of two elements: the basic daily demand in the peak periods of service, and the number of spare vehicles required so that breakdowns and performance of maintenance will not disrupt the service. When purchasing buses, because seating capacity and operating speed are covered by performance specifications, the basic daily vehicle demand does not vary. However, the number of spare vehicles required will depend on the reliability (frequency of breakdown) and the time required for maintenance of the vehicles and auxiliary vehicle equipment, such as air conditioners, fareboxes, and wheelchair lifts.

Policy on performance of scheduled service, availability of spare vehicles of other types, and the type of service are important conditions for determining fleet size requirements. In each case, the analyst must consider all the factors and develop an analytical procedure that best represents the constraints in the particular case. The discussion that follows illustrates the rigorous case of a small fleet providing a fixed-route, scheduled service.

Availability Factors — Vehicle availability can be defined as the percentage of time that a vehicle is operating, or ready to operate, during the periods of regular scheduled service. Vehicles that break down while in service and require replacement are included in the inoperable totals.

For any bus, availability can usually be calculated from data on maintenance and repairs. The controlling period of the day is the period of peak demand for vehicles, as this demand establishes the minimum acceptable fleet size. During this period of the day, it is common practice to schedule only that maintenance necessary to make vehicles serviceable or to perform routine maintenance on vehicles that are not needed on the street. Other preventive maintenance and scheduled repairs will be performed during off-peak periods. Therefore, the availability factor is calculated by dividing the hours when a vehicle is either in service or available for service during the peak period (or total number of peak-demand hours minus the number of hours during the peak when the vehicle is broken-down and undergoing essential repairs) by total hours of the peak demand.

When maintenance records and test data are being evaluated, judgment must be used in deciding whether repair work puts a vehicle out of service. For example, a bus with a brake failure is not safe and must be repaired, but repair of out-of-order air-conditioning can usually be deferred to an off-peak period of the day. Also, test data and maintenance records may include periods when vehicles were out of service because of authorized modifications, accidents, or similar unusual incidents. Such time should be excluded from the availability calculation by omitting it from both downtime and total peak demand time. However, the operator may wish to include a downtime allowance for accident repairs (normally a function of site experience independent of vehicle type and, therefore, a constant for all competing vehicles) in the final availability factor.

Fleet Size — The required size of the bus fleet, including spares, can be calculated using the availability factor, adjusted to allow for the randomness of breakdowns. Availability is an average representing the portion of time a vehicle will be available for service; however, in a fleet of vehicles, several may be out of service at any one time. In fact, in any fleet of vehicles, there is a small but finite probability that all (or fifty percent, etc.) will be out of service at one time. Thus, it is impractical to purchase enough vehicles to meet the demand at all times. The operator should establish a goal for meeting demand (e.g., having enough vehicles for all scheduled service a definite portion of the time). For example, it may be considered acceptable to degrade peak period service on one day out of two weeks, one day a month, or one day out of the two months. This is equivalent to a policy that demand will be met ninety percent, ninety-five percent, or ninety-eight percent of the time, respectively.

In a small fleet of buses, the statistical interaction of random breakdowns and service policy can be very significant and can be calculated using the Binomial Distribution Tables (found in most basic statistics texts). The table below illustrates the impact of statistical distribution of downtime on fleet size, when demand is to be met ninety-five percent of the time. Taking the first line as an example, this table shows that, for a fleet of thirteen vehicles where the average amount of downtime per vehicle is one day in ten (ninety percent availability), on nineteen days out of twenty there will be ten or more vehicles available for service.

Table 2. Required Fleet Size

Average Bus Availability	Peak Period Buses Req'd	Policy on Time Demand Met	Required Fleet Size
90%	10	95%	13
85%	10	95%	14
80%	10	95%	16

For vehicle demands of fewer than fifty units, statistical distribution of downtime is an important consideration in determining fleet size. For larger fleets, this effect can usually be ignored and fleet size can be calculated by dividing demand by the availability factor and allowing two or three additional units for contingencies. Similar options are appropriate if other types of vehicles are available for assignment on a temporary basis or if the type of service permits occasional degraded levels of service (as may be the case with some demand-responsive services).

Fleet size requirements should be incorporated in the final life-cycle cost by factoring the cost per unit upward. For example, assume a purchase of twelve vehicles is planned (ten-vehicle demand plus two spares), and a fleet of fourteen units of one particular candidate is required to meet the demand. The LCC for buses in the 14-vehicle fleet can be normalized to twelve by multiplying the elements of the LCC that are independent of mileage(16) (e.g., initial purchase price, salvage value, and any maintenance or servicing, such as annual rehabilitation of air conditioners, that is not based on mileage) by the ratio of fourteen to twelve (normalized LCC equals LCC per vehicle times 1.167). A fleet size requirement of less than the proposed buy (i.e., eleven in the above case) should not be factored into the LCC calculation. This is because other considerations, such as flexibility of scheduling and the possibility of accidents, enter into the determination of the basic fleet requirement. However, the high reliability and availability associated with a low fleet size requirement may be a consideration in the evaluation of bids when total life-cycle costs are very close. High fleet size requirements may have serious implications beyond the LCC comparison (e.g., if storage space or maintenance facilities are severely limited) and, therefore, may be cause for rejection of an otherwise competitive bid.

DISCOUNT AND INFLATION RATES

Since LCC evaluation may involve projecting costs for six or more years, estimates of future costs should be adjusted for inflation and discounted to net present value. The discount rate is equivalent to the cost of capital as measured by the borrowing cost to the organization undertaking the expenditure. The U.S. Office of Management and Budget recommends a discount rate of ten percent for comparing projected future income and benefits with the investment required for capital intensive public works projects. However, the analysis of life-cycle costs differs in two major ways from the situations for which the OMB rate is recommended:

- The time period is relatively short and the actual amount to be deferred is only a small percentage of the total amount involved in the purchase. That is, in comparing two vehicles, the total costs are similar in magnitude, and both involve a substantial initial expenditure followed by annual expenditures for fuel and maintenance.

- The determination of LCC does not involve a cost/benefit analysis. The decision to purchase small buses has been made in advance of the LCC analysis. The evaluation involves which of the candidate buses to purchase, and is essentially a choice between different expenditure patterns. It is thus entirely cost oriented, rather than cost/benefit oriented, so there is no "risk" that the forecast benefits will not be realized.

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16 Fleet mileage is determined by passenger demand and service policy, and is independent of the number of vehicles in the fleet. Therefore, in adjusting for additional vehicles in the fleet, the mileage related costs should not be adjusted.

Inflation of future costs reflects the anticipated increases in costs, a function of reduced purchasing power of money. The discount rates that are usually selected reflect the devaluation of money in the future, as well as the cost for the use of money. The real cost of money is represented by the difference between the discount rate and the inflation rate — usually about two percent. The two rates — inflation and discount - are related and should be selected (and compared) with this relationship in mind.

Establishing the Discount Rate

The interest rate on U.S. Treasury notes of duration equivalent to the estimated life of small transit vehicles, is one measure of cost of capital. This cost reflects the private sector's willingness to defer its expenditures in exchange for interest payments. The use of rates for securities with maturity approximating the life of the vehicles provides a sound basis for discounting. The funds will be "paid back" during the life-cycle, so that a "borrowing" for the period of the life-cycle would be a close estimate of the true borrowing cost.

Therefore, the recommended discount rate for LCC analysis of small bus procurements is the average rate of the market yield for Treasury obligations with similar life or maturity. This rate is readily available from daily financial publications (e.g., The Wall Street Journal).

Establishing the Inflation Rates

The rate of inflation is basically an increase in the cost of goods and services. The buyer can reasonably expect that inflation will affect the cost of operating a small bus in future years, so adjustments to annual operating cost should be made. The adjustment should be made prior to discounting to obtain net present value.

Applicable rates are obtainable from the Monthly Labor Review, published by the Bureau of Labor Statistics. References for applicable indices and corresponding inflation rates are the following:

- Fuel and Lubricants — Wholesale Price Index of Refined Petroleum Products, Code 05-7;
- Replacement Parts and Salvage Value — Wholesale Price Index of Motor Vehicles and Equipment, Code 14-1; and
- Labor Rates — Effective Wage Adjustments going into Effect in Major Collective Bargaining Units.

To obtain the annual inflation rate the following equation may be used:

$$I = \frac{\text{Current Price Index - Previous Year Price Index}}{\text{Previous Year Price Index}}$$

As an alternative labor inflator, the analyst may use negotiated rates contained in the transit property's current labor contract (or a combination of contractual increases and predicted cost-of-living adjustments).

Computing Net Present Value

Inflation factors are applied to estimated annual operating costs as follows:

1. Estimate the cost per mile in current dollars of each element of operating costs (fuel, labor, parts).

2. Multiply by the estimated miles to be operated in each year of the useful life.

3. Adjusted Cost = Cost (in current dollars) times $(1 + I)^n$, where n is the number of years after the current year and I is the inflation rate.

After adjusting for inflation, costs may be totaled by years and then discounted to net present value. Discounted value = Total Annual Cost divided by $(1 + i)^n$, where i is the discount (or interest) rate and n is the number of years after the current year.

THE ESTIMATED LCC

To determine the estimated life-cycle cost for each vehicle model, the analyst compiles the LCC elements, including:

- Initial Unit Price;
- Average Annual Operating Cost for each year of use; and
- Unit Salvage Value.

The analyst then adjusts for inflation, present worth of future value (discount) and fleet size requirements. Initial unit price and first year operating costs will not require adjustment for inflation or discount but may be affected by fleet size requirements. The final life-cycle cost is the sum of the adjusted elements over the useful life of the vehicle. In calculating the sum, care must be taken to insure that those cost elements that decrease the life-cycle cost (i.e., salvage value) are accounted for properly.

A simplified example of the life-cycle cost analysis is presented in Appendix B. This example may be used as a model for the organization and sequence of the calculations and for the format of tables presenting the analytical development of the life-cycle costs.

SPECIAL CONSIDERATIONS

The analyst should expect to encounter conditions that differ from the normal pattern of life-cycle cost analysis and require special handling. It is impossible to anticipate or describe all such conditions, but the following examples suggest some exceptions that may arise and possible techniques for dealing with them.

Accessories and Auxiliary Equipment

Most transit vehicles are fitted with several pieces of equipment that affect the operation and reliability of the vehicle. This equipment includes such items as a farebox or fare collection system, a two-way radio or other communication devices, route and destination displays, and wheelchair lifts. Some equipment such as air conditioners may be treated as auxiliary equipment rather than as a subsystem of the basic vehicle. The decision on inclusion of maintenance costs for this equipment in the life-cycle cost of the vehicle should be based on whether the equipment is common to all vehicles and whether overall equipment maintenance experience can be shown to vary for different vehicle models. If the auxiliary equipment maintenance costs can be shown to be independent of vehicle type or manufacturer, as can be reasonably presumed for fare boxes, then these costs can be omitted from the evaluation. On the other hand, some of the equipment maintenance costs may be associated with vehicle performance, in which case, either all maintenance costs for that type of equipment or costs of certain types of work should be included. As an example, a high rate of radio power supply failure may be associated with voltage surges from the electrical system on one type of vehicle. Such costs should be charged to the vehicle.

Auxiliary equipment maintenance that is not charged to the vehicle cannot be dismissed entirely. Since much of this equipment is permanently (or semipermanently) installed in the vehicle, failures and downtime of the equipment will take the vehicle out of service. Therefore, in arriving at a basic fleet size (peak vehicle demand plus spares) one element to be considered is in the frequency of failure and time required for repairs of auxiliary equipment.

Product Improvements

One of the objectives of the LCC approach to procurement is to create a climate that encourages product improvements and the correction of deficiencies noted in service. However, product improvements that affect operating costs may present significant problems for the analyst. Initial purchase price of the vehicle will include the added cost (or savings) resulting from the change, but operating experience may be totally lacking. The analyst may have little basis for estimating the value of the improvement (i.e., the change in operating costs) except for the claims of the manufacturer. The analyst also has an obligation to credit the value of the improvement in a manner that is equitable to all competitors. The design and prior performance of the altered components and subsystems should be evaluated as a basis for assessing the extent of the change from past performance that can be expected. A reasonable cost adjustment should then be determined, taking into account the uncertainty regarding the effectiveness of the change.

Parts Availability

Ready availability of replacement parts and components permits the transit operator to limit the inventory of parts on hand, without incurring a high risk of having vehicles out of service while waiting for parts. Large inventories require a significant investment and extensive storage space, each of which represents a cost to the operator. Therefore, it may be important to consider parts supply experience when analyzing life-cycle costs. If parts resupply is found to be slower than anticipated, stock levels should be increased to insure that needed parts will be available. Also, it may be necessary to stock some major items that would normally be ordered only when needed.

APPENDIX A

MAINTENANCE DATA FORMS

VEHICLE MILES JOURNAL

VEHICLE OPERATION DATE 1		
MONTH	DAY	YEAR

VEHICLE NUMBER 2	TOTAL MILEAGE TO DATE 3	MILES THIS DATE 4	VEHICLE NUMBER 5	TOTAL MILEAGE TO DATE 6	MILES THIS DATE 7

8
WRITTEN BY ____ DATE ____

9
INSPECTED BY ____ DATE ____

FIGURE A-1. Vehicle Miles Journal

VEHICLE SERVICING PERFORMED JOURNAL				VEHICLE SERVICING DATE 1		
				MONTH	DAY	YEAR

VEHICLE NUMBER 2	FUEL (GALLONS) 3	OIL (QUARTS) 4	COOL-ANT (QUARTS) 5	VEHICLE NUMBER 6	FUEL (GALLONS) 7	OIL (QUARTS) 8	COOL-ANT (QUARTS) 9

10		11	
WRITTEN BY	DATE	INSPECTED BY	DATE

FIGURE A-2. Vehicle Service Performed Journal

VEHICLE REPAIR, MATERIALS AND LABOR JOURNAL

VEHICLE REPAIR DATE 1

MO. DAY YR.

NUMBER 2	TOTAL MILEAGE TO DATE 3	PERSONNEL NUMBER 4	GROUP 5	UNIT 6	ELAPSED TIME 7 (HRS. / MINS.)	RECORD TIME HERE 8
WORK ORDER NUMBER 9	IF A CONTINUATION REPORT CHECK HERE ☐ 10 ORIGIONAL REPORT NO.					OUT / IN
REPAIR DESCRIPTION 11						OUT / IN
						OUT / IN
						OUT / IN
						OUT / IN
						OUT / IN
						OUT / IN
						OUT / IN

Enter Parts Used In Repair

ITEM DESCRIPTION 12	HOUSE INVENTORY NUMBER 13	QUANTITY 14	ISSUE UNIT 15

16 MANUFACTURER REPRESENTATIVE DATE

17 TRANSIT AUTHORITY REPRESENTATIVE DATE

FIGURE A-3. Vehicle Repair, Materials and Labor Journal

VEHICLE OPERATING AND MAINTENANCE COST REPORT		VEHICLE NUMBER 1
Vehicle Assignment and Miles Record	PAGE OF	

DATE 2			MODEL YEAR 3	MAKE 4
MONTH	DAY	YEAR		

NOTES (Describe uncontrolled events and method used to account for their impact on vehicle operation and maintenance; for example, inoperative period and excessive maintenance resulting from vandalism.) 5

DATE 6			TOTAL MILES TO DATE 7	PERIOD MILES 8
MONTH	DAY	YEAR		
			ACCUMULATED PRIOR MILEAGE 9	TOTAL MILES TRAVELED

FIGURE A-4. Vehicle Assignment and Miles Record

VEHICLE OPERATING AND MAINTENANCE COST REPORT

Vehicle Number [1]

Commodity Cost Record

PAGE ___ OF ___

Service Center Constants (Dollars)

CONSTANTS DATE [2]			FUEL PRICE PER GALLON [3]	OIL PRICE PER QUART [4]	COOLANT PRICE PER QUART [5]
MO.	DAY	YR.			

Commodity Cost

VEHICLE SERVICE DATE [6]			FUEL			OIL			COOLANT		
MO.	DAY	YR.	ADDED [7]	PRICE [8]	COST [9]	ADDED [10]	PRICE [11]	COST [12]	ADDED [13]	PRICE [14]	COST [15]
PERIOD COST [16]											
ACCUMULATED PRIOR COST [17]											
CUMULATIVE TOTAL COST [18]											

FIGURE A-5. Commodity Cost Record

VEHICLE OPERATING AND MAINTENANCE COST REPORT

VEHICLE 1

Maintenance Labor Record

PAGE ___ OF ___

ELAPSED TIME 2		3	UNIT 4	PERSONNEL NUMBER 5	HOURLY PAY RATE 6	WORK ORDER NUMBER 7	LABOR COST 8
HRS.	MINS.						
PERIOD COST 9							
ACCUMULATED PRIOR COST 10							
CUMULATIVE TOTAL COST 11							

FIGURE A-6. Maintenance Labor Record

VEHICLE OPERATING AND MAINTENANCE COST REPORT	VEHICLE NUMBER 1
Material Issue and Return-to-Stores Record	PAGE OF

MAINTENANCE DATE 2			HOUSE INVENTORY NUMBER 3	QUANTITY 4	UNIT OF ISSUE 5	GROUP 6	UNIT 7	UNIT PRICE 8	MATERIAL COST 9
MO.	DAY	YR.							
PERIOD COST								10	
ACCUMULATED PRIOR COST								11	
CUMULATIVE TOTAL COST								12	

FIGURE A-7. Material Issue and Return-to-Stores Record

APPENDIX B
EXAMPLE OF LIFE-CYCLE COST ANALYSIS

This simplified LCC analysis is only an example and does not represent an actual procurement. However, the data used have been selected to fall within the realistic range and to suggest values and relationships that might be encountered in an actual procurement. The basic LCC analysis consists of four major steps:

- Compilation of vehicle operating cost data, and projection of future costs;
- Estimation of salvage value;
- Adjustments for inflation, discount, and availability rates; and
- Determination of total life-cycle costs.

The example considers three different competing vehicle models — X, Y, and Z — and assumes a six-year useful life during which each vehicle will be operated an average of 50,000 miles annually. The basic fleet requirement is 12 vehicles, made up of a peak demand for 10 vehicles and 2 spares. Annual operation of the fleet is 600,000 miles or 3,600,000 miles during the fleet's six-year life.

Compilation of Operating Costs

The analyst compiles all available performance and operating cost data for each competing vehicle. These data are derived from tests and operating experience and relate primarily to maintenance, and fuel and other commodities consumed. Maintenance costs to be used include all expenses for labor and materials used in preventive, scheduled and unscheduled maintenance of all vehicles. The commodity costs include costs of fuel, oil and coolant consumed. Other operating costs, such as drivers' wages, are generally assumed to be the same for all competitors and therefore may be omitted from the analysis.

Table B-1 summarizes operating cost data assembled for this example. These unit costs are based on available data adjusted, by the analyst, to conform to the set of conditions that applies to each of the vehicles during the analysis period (i.e., useful life). Table B-2 contains the annual costs obtained by multiplying costs per mile times the annual miles of operation.

Unit costs are multiplied by the appropriate units (usually miles per year) to obtain annual costs for three principal categories: maintenance labor, maintenance parts, and commodities. In the example, first year maintenance costs have been increased by the addition of a fixed amount for

Table B-1. Average Unit Operation Cost[1]

Cost Categories	Units	Vehicle X	Vehicle Y	Vehicle Z
Maintenance-First Year				
Labor	$/mile	0.0277	0.0112	0.0546
Parts	$/mile	0.0153	0.0261	0.0321
Wear-in[2]	$	204	158	320
Annual Increment[3]				
Labor	$/mile	0.0011	0.0044	0.0025
Parts	$/mile	0.0006	0.0009	0.0014
Commodities				
Fuel	$/mile	0.0467	0.0449	0.0599
Oil	$/mile	0.0006	0.0005	0.0008

1. Current dollars.
2. Add to First Year Labor Costs only. May be zero or negative if the vehicle is under warranty.
3. Annual Increase in maintenance costs—cumulative.

Table B-2. Projected Annual Costs (50,000 miles/year)

Year	Cost Category	Vehicle X	Vehicle Y	Vehicle Z
1	Maintenance Labor	$1,589	$ 718	$3,050
	Maintenance Parts	765	1,305	1,605
	Commodities[1]	2,365	2,270	3,035
2	Maintenance Labor	1,440	580	2,855
	Maintenance Parts	795	1,350	1,675
	Commodities	2,365	2,270	3,035
6	Maintenance Labor	1,660	660	3,355
	Maintenance Parts	915	1,530	1,955
	Commodities	2,265	2,270	3,035

1. Fuel and Oil combined.

wear-in costs of new vehicles, and would be decreased by the value of work done under warranty, if applicable. Second and subsequent year costs are increased by the addition of a cummulative increment to account for the gradual increase in frequency and extent of maintenance activity. Both wear-in costs and time-rates of increase of maintenance activity are based on the operating cost and performance data.

Estimation of Salvage Value

The salvage value is defined as the fair market value of the vehicle at the end of its useful life. This estimate of salvage value can be based on the recent price received by sellers for vehicles of the same or similar models and age equal to the useful life of the vehicles being analyzed. The usual sources of such data are used bus dealers and appraisal consultants. Applicable data (e.g., similar, or the same, model and age) should be adjusted for differences in equipment (e.g., air conditioning, automatic transmission, wheelchair lifts) that would remain on the vehicles when sold. If directly applicable data are not available, a salvage value may be calculated based on the proportional difference between recent new and used prices for like buses of comparable capacity and new cost. The salvage value, determined by either technique, is in current dollars and should be adjusted for inflation and discount. Initial Purchase Prices and Salvage Values assumed for this example are shown in Table B-3.

Table B-3. Purchase Price and Salvage Value

Category	Units	Vehicle X	Vehicle Y	Vehicle Z
Initial Purchase Price	$	53,500	36,800	34,200
Salvage Value (6 years)	$	12,500	11,400	7,800

Adjustments to LCC

Three adjustments should be made to life-cycle cost elements before determining the total life-cycle cost. Inflation and discount adjustments are applied to operating costs and salvage value after the first year. Availability adjustments apply primarily to initial price and salvage value.

Inflation — Because the LCC analysis includes costs that will be incurred in the future, adjustments for inflations should be used to provide a more realistic estimate of actual costs. The inflation facotrs can be based on wholesale price indices and wage adjustment rates reported in the

26. Wholesale Price Index, by group and subgroup of commodities

[1967 = 100 unless otherwise specified]

Code	Commodity group	Annual average 1976	1976		1977										
			Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
	All commodities	183.0	185.6	187.1	188.1	190.2	192.0	194.4	195.2	194.4	194.9	194.6	195.3	196.3	197.0
	All commodities (1957–59 = 100)	194.2	196.9	198.5	199.6	201.8	203.6	206.2	207.1	206.3	207.6	206.5	207.2	208.3	209.0
	Farm products and processed foods and feeds	183.1	178.3	183.9	184.8	188.4	190.9	195.9	196.5	191.5	189.3	184.2	183.9	184.2	186.8
	Industrial commodities	182.4	187.1	187.4	188.4	190.1	191.7	193.3	194.2	194.6	195.8	196.9	197.6	199.1	199.2
	FARM PRODUCTS AND PROCESSED FOODS AND FEEDS														
01	Farm products	191.0	183.6	191.6	193.5	199.1	202.5	208.2	204.3	192.7	190.5	181.2	181.9	182.4	185.5
01-1	Fresh and dried fruits and vegetables	178.4	166.5	174.5	198.5	212.7	219.2	205.7	201.8	176.2	182.0	176.4	182.8	187.9	192.9
01-2	Grains	205.9	175.4	180.6	184.9	185.8	183.4	184.4	171.2	157.7	153.3	142.5	144.2	144.7	164.6
01-3	Livestock	173.3	154.4	166.1	166.0	166.2	163.5	167.9	180.2	172.3	180.5	175.2	172.9	177.5	171.6
01-4	Live poultry	168.9	139.1	145.7	153.7	183.7	177.2	182.3	183.1	182.7	193.7	178.1	181.7	170.5	162.7
01-5	Plant and animal fibers	223.9	257.9	239.5	216.5	240.1	252.4	249.5	238.6	197.5	195.3	180.3	165.6	166.9	164.1
01-6	Fluid milk	201.2	204.4	202.8	200.2	198.4	195.2	197.7	198.3	199.3	202.7	202.7	206.7	209.6	209.8
01-7	Eggs	179.1	192.8	213.6	189.2	194.8	173.5	165.2	144.4	141.4	156.6	162.0	183.3	137.6	149.4
01-8	Hay, hayseeds, and oilseeds	210.4	231.9	242.3	244.9	254.5	278.0	322.4	289.8	270.2	207.7	197.7	178.2	178.2	193.5
01-9	Other farm products	223.4	271.3	290.6	296.0	314.0	366.4	386.3	357.5	341.1	334.0	279.1	316.3	303.7	302.6
02	Processed foods and feeds	178.0	174.8	179.0	179.3	181.9	183.9	188.5	192.0	190.1	187.6	185.1	184.2	184.5	186.7
02-1	Cereal and bakery products	172.1	168.7	168.6	166.4	169.9	171.5	171.6	172.0	171.3	172.0	172.1	172.8	175.4	179.7
02-2	Meats, poultry, and fish	181.6	186.4	176.9	176.6	177.4	174.2	174.9	183.8	183.4	189.5	182.7	182.7	184.7	183.4
02-3	Dairy products	168.5	166.1	167.3	166.8	166.6	168.0	173.5	174.2	174.3	175.1	175.3	175.7	175.9	176.9
02-4	Processed fruits and vegetables	170.2	175.7	175.6	175.2	182.7	184.0	185.2	185.8	187.8	188.5	190.1	191.2	190.3	193.0
02-5	Sugar and confectionery	190.9	171.4	170.5	171.9	177.6	180.2	188.4	184.4	176.3	172.7	180.2	174.3	170.1	177.8
02-6	Beverages and beverage materials	173.5	178.8	183.6	184.1	189.3	199.6	202.1	206.0	207.7	204.7	205.5	204.8	204.3	200.6
02-71	Animal fats and oils	210.2	231.5	230.9	240.9	253.0	253.0	305.8	307.7	279.9	258.7	252.0	243.6	276.5	270.0
02-72	Crude vegetable oils	182.5	188.0	178.4	171.8	190.0	222.9	253.7	248.6	229.6	181.0	180.7	155.2	184.3	175.0
02-73	Refined vegetable oils	187.5	190.3	185.2	185.7	204.9	219.9	229.1	228.9	219.2	182.0	173.3	182.8	179.7	189.9
02-74	Vegetable oil end products	174.2	180.6	178.3	177.9	182.7	187.8	206.3	214.1	218.3	209.6	199.9	202.0	197.0	192.3
02-8	Miscellaneous processed foods	174.7	178.1	182.8	182.1	183.8	183.8	184.8	192.4	192.9	194.1	194.1	193.9	193.9	191.9
02-9	Manufactured animal feeds	194.4	200.2	213.2	218.9	218.6	221.8	243.0	239.6	225.7	194.4	176.5	175.3	171.3	194.0
	INDUSTRIAL COMMODITIES														
03	Textile products and apparel	148.2	150.1	149.9	150.8	151.7	152.4	153.7	154.0	154.4	154.4	154.4	155.1	155.2	155.3
03-1	Synthetic fibers[1]	102.4	101.7	101.6	102.4	103.3	103.2	106.4	107.0	109.5	109.2	109.6	109.6	109.5	109.6
03-2	Processed yarns and threads[1]	99.5	97.5	97.2	98.8	97.5	98.7	101.5	102.3	103.4	103.4	100.0	102.1	101.2	100.4
03-3	Grey fabrics[1]	106.1	109.1	107.7	106.0	104.7	104.5	105.0	105.1	104.5	104.9	103.3	103.0	103.7	105.2
03-4	Finished fabrics[1]	101.1	101.4	101.5	100.8	101.8	103.0	104.3	104.9	104.5	104.3	104.2	104.2	104.1	103.3
03-5	Apparel	139.9	142.8	142.9	145.3	145.7	146.0	146.5	146.6	147.2	147.2	147.4	148.4	148.6	149.1
03-6	Textile housefurnishings	159.3	163.2	162.7	165.5	170.4	170.4	170.4	169.7	169.7	169.7	171.2	174.7	175.6	175.6
04	Hides, skins, leather, and related products	167.8	169.8	171.5	175.3	176.9	177.9	179.9	181.9	179.7	180.3	180.5	179.9	179.6	180.3
04-1	Hides and skins	258.4	231.8	251.2	278.9	282.5	285.9	305.0	313.0	268.8	291.5	288.3	274.4	268.3	273.2
04-2	Leather	186.1	191.4	191.7	199.5	201.3	201.4	204.1	210.7	202.1	198.6	200.3	200.5	196.4	197.0
04-3	Footwear	158.9	162.6	162.9	164.4	165.5	166.4	167.2	167.7	168.2	170.3	170.4	170.5	171.7	172.0
04-4	Other leather and related products	152.9	155.9	156.2	159.5	161.4	162.6	163.2	163.7	163.7	163.8	164.2	164.5	164.4	164.7
05	Fuels and related products and power	265.6	281.6	279.0	278.8	289.1	293.7	298.8	302.3	304.0	306.6	309.5	309.7	310.6	310.4
05-1	Coal	368.7	369.1	374.0	376.2	377.4	378.8	379.8	386.9	390.6	393.0	394.5	395.2	397.6	400.1
05-2	Coke	346.8	349.7	363.4	367.3	367.3	367.3	372.9	375.1	386.1	386.1	386.1	386.1	386.1	386.1
05-3	Gas fuels	286.8	365.0	337.6	322.2	363.7	370.9	379.0	390.2	386.6	391.9	400.9	405.4	407.0	414.1
05-4	Electric power	207.6	214.0	211.5	213.8	219.7	223.4	229.4	230.7	234.4	239.2	244.7	242.7	242.6	237.8
05-61	Crude petroleum	253.6	264.4	264.4	262.9	274.2	270.0	271.0	271.0	271.8	270.8	273.1	276.1	278.6	282.9
05-7	Petroleum products, refined	276.6	285.8	287.6	289.6	295.6	301.9	306.8	310.1	311.6	312.9	313.0	312.6	313.8	313.4
06	Chemicals and allied products	187.2	188.6	188.2	189.0	190.2	191.2	193.0	193.8	193.9	193.5	193.5	193.2	193.5	193.8
06-1	Industrial chemicals	219.3	222.6	221.5	221.9	223.0	222.4	223.5	224.0	224.1	224.4	224.7	224.2	224.7	224.9
06-21	Prepared paint	174.4	177.3	177.3	177.3	177.3	176.9	180.6	181.7	182.3	183.9	183.9	185.1	185.1	186.7
06-22	Paint materials	189.6	200.3	200.7	200.6	202.3	206.1	209.4	210.1	209.3	206.6	206.8	204.9	203.6	204.3
06-3	Drugs and pharmaceuticals	134.0	135.9	136.4	137.5	138.5	139.0	139.6	139.7	140.8	141.2	141.2	141.4	141.6	142.2
06-4	Fats and oils, inedible	249.9	251.2	254.6	255.0	268.1	273.7	304.9	337.5	318.8	281.9	268.9	248.9	260.9	265.4
06-5	Agricultural chemicals and chemical products	188.4	184.1	183.4	182.3	183.9	187.1	189.7	187.7	189.0	186.4	188.9	189.9	190.0	188.1
06-6	Plastic resins and materials	194.0	195.4	194.9	193.4	192.9	194.6	195.9	196.6	197.6	199.7	199.6	200.2	199.8	199.4
06-7	Other chemicals and allied products	170.7	169.9	169.4	172.4	173.5	174.6	175.4	175.9	176.0	175.9	176.3	176.4	176.4	177.2
07	Rubber and plastic products	159.2	164.8	164.7	164.6	164.2	164.6	165.7	166.4	167.4	168.9	169.1	169.4	170.0	170.0
07-1	Rubber and rubber products	163.2	171.5	171.4	171.1	166.8	169.3	171.8	172.3	172.9	174.9	175.1	175.8	176.7	176.8
07-11	Crude rubber	161.0	164.9	163.2	163.9	165.2	166.9	168.5	169.7	171.4	172.0	172.4	176.2	177.2	177.1
07-12	Tires and tubes	161.5	172.1	172.3	170.3	165.3	165.6	169.9	167.6	167.8	171.3	171.1	171.1	171.9	171.6
07-13	Miscellaneous rubber products	163.9	170.6	170.9	172.4	172.0	172.3	173.1	176.3	177.3	177.9	176.7	179.1	180.2	180.6
07-21	Plastic construction products[2]	127.2	129.4	129.4	129.5	129.6	129.8	128.9	130.5	134.1	136.5	136.7	136.0	136.1	135.7
07-22	Unsupported plastic film and sheeting[3]	154.9	157.5	157.5	157.6	159.5	159.6	159.2	159.6	160.3	160.9	161.0	161.2	161.7	161.7
07-23	Laminated plastic sheets, high pressure[3]	131.1	137.6	137.2	136.5	137.3	138.3	141.6	142.2	142.4	143.1	142.9	142.9	142.1	142.6
08	Lumber and wood products	205.6	214.3	220.0	222.6	224.4	229.0	229.6	229.3	226.7	235.5	242.7	252.4	247.3	243.2
08-1	Lumber	233.0	244.3	252.1	257.9	259.4	266.4	268.8	267.8	264.6	275.9	286.4	301.3	292.4	284.6
08-2	Millwork	176.9	183.0	183.1	183.6	186.1	188.3	190.7	191.5	192.4	192.2	194.8	197.6	199.0	202.5
08-3	Plywood	187.0	194.4	205.2	204.6	204.8	207.9	202.5	200.0	202.6	211.9	219.8	229.6	221.7	212.8
08-4	Other wood products	166.2	171.3	172.5	173.2	176.4	178.9	181.0	184.4	185.4	185.6	186.5	189.6	189.8	189.8

See footnotes at end of table.

FIGURE B-1 Wholesale Price Index

26. Continued—Wholesale Price Index, by group and subgroup of commodities

[1967 = 100 unless otherwise specified]

Code	Commodity group	Annual average 1976	1976		1977										
			Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
	INDUSTRIAL COMMODITIES—Continued														
09	Pulp, paper, and allied products	179.4	181.5	181.8	182.9	183.0	183.6	185.3	186.1	187.3	187.7	187.8	188.5	188.8	188.3
09-1	Pulp, paper, and products, excluding building paper and board	180.8	181.5	181.8	184.2	184.3	184.9	186.5	187.3	188.4	188.6	188.5	189.1	189.3	188.6
09-11	Woodpulp	266.0	265.2	265.2	264.3	263.7	263.7	266.3	266.8	265.7	265.7	262.0	260.4	279.8	276.7
09-12	Wastepaper	184.9	183.9	178.4	177.8	177.4	180.6	181.8	185.3	186.3	186.3	183.6	187.3	191.1	201.3
09-13	Paper	182.3	186.2	186.6	189.1	189.4	192.0	193.3	194.1	194.3	195.6	196.2	196.3	197.1	197.5
09-14	Paperboard	176.0	177.0	175.7	174.5	173.4	172.4	174.5	179.0	179.5	180.6	180.4	180.1	177.8	174.2
09-15	Converted paper and paperboard products	170.0	171.9	172.5	173.7	174.0	174.0	175.6	175.7	177.4	177.2	177.2	178.1	178.5	178.2
09-2	Building paper and board	138.6	142.3	144.2	145.2	144.5	145.9	148.8	151.3	153.8	157.8	162.4	166.7	168.8	168.3
10	Metals and metal products	195.9	200.1	200.9	202.1	203.2	206.5	208.2	208.6	207.8	210.7	211.7	212.6	211.8	212.0
10-1	Iron and steel	215.9	218.9	222.6	224.3	224.8	227.4	228.3	227.9	226.9	232.1	233.1	235.7	234.2	233.4
10-13	Steel mill products	209.8	216.4	220.7	221.3	221.3	223.8	224.4	225.3	225.4	233.4	234.4	237.5	237.5	237.3
10-2	Nonferrous metals	181.6	187.5	185.1	186.3	189.4	195.8	200.1	200.9	197.3	198.0	198.5	195.1	193.5	194.2
10-3	Metal containers	202.2	204.5	204.6	204.5	204.6	216.7	217.0	216.8	218.9	217.5	218.3	225.1	226.5	227.1
10-4	Hardware	173.1	177.1	179.2	181.5	182.5	183.3	183.6	183.6	184.5	186.8	186.7	187.4	186.6	187.8
10-5	Plumbing fixtures and brass fittings	174.1	179.2	179.2	179.5	179.7	182.2	182.8	184.9	186.1	189.3	189.8	190.6	190.9	191.1
10-6	Heating equipment	158.0	160.9	161.8	162.9	163.1	163.7	163.5	164.0	164.5	165.4	166.0	166.8	168.0	168.3
10-7	Fabricated structural metal products	193.8	198.0	198.9	199.4	200.3	201.7	203.1	204.2	205.0	208.0	210.2	212.0	212.0	212.4
10-8	Miscellaneous metal products	186.9	191.0	190.7	191.6	191.9	192.3	192.4	193.3	194.9	197.3	198.6	200.2	201.0	201.9
11	Machinery and equipment	171.0	174.5	175.4	176.7	177.5	178.2	178.9	180.0	180.8	181.9	182.8	183.9	[1]185.7	186.7
11-1	Agricultural machinery and equipment	183.0	188.8	190.8	192.3	193.5	194.5	194.8	195.1	196.0	196.6	198.4	200.4	201.4	204.1
11-2	Construction machinery and equipment	198.9	204.5	205.8	207.2	208.0	208.3	210.2	213.0	213.2	214.9	215.8	215.7	218.3	221.4
11-3	Metalworking machinery and equipment	182.7	187.2	188.7	190.9	192.7	193.7	194.7	195.7	197.9	199.2	200.6	201.7	203.6	204.4
11-4	General purpose machinery and equipment	189.8	193.7	194.5	195.9	196.7	197.5	198.3	200.2	201.5	202.6	203.5	204.4	205.4	206.6
11-6	Special industry machinery and equipment	188.4	192.0	193.8	195.4	196.4	197.2	199.1	200.9	202.1	203.0	204.0	204.4	209.8	210.2
11-7	Electrical machinery and equipment	146.7	149.5	150.0	150.8	151.4	151.9	152.0	152.7	153.0	154.1	154.6	155.8	[1]157.3	157.8
11-9	Miscellaneous machinery	171.9	174.5	175.1	176.1	176.9	177.4	178.0	179.2	179.4	180.7	181.8	183.3	184.0	185.1
12	Furniture and household durables	145.8	147.5	147.9	148.8	149.1	149.6	150.1	150.5	151.3	151.2	152.4	152.5	153.0	153.6
12-1	Household furniture	153.6	157.5	158.6	158.6	158.9	159.7	160.7	161.1	162.2	162.8	163.1	163.1	164.1	165.1
12-2	Commercial furniture	173.5	176.4	176.4	177.3	178.2	178.8	183.3	184.9	186.7	184.4	191.0	190.8	190.8	192.2
12-3	Floor coverings	131.4	131.6	131.8	135.5	135.5	135.6	135.6	135.5	135.8	136.1	136.5	136.6	137.1	138.1
12-4	Household appliances	139.2	140.6	141.0	141.3	142.2	142.9	143.3	143.2	144.6	145.4	146.2	147.1	147.4	147.5
12-5	Home electronic equipment	91.3	91.0	90.9	89.7	89.4	89.4	88.3	88.4	88.3	86.8	86.8	86.3	86.3	86.4
12-6	Other household durable goods	179.1	182.9	183.3	187.5	188.0	188.4	187.9	189.2	189.5	190.2	190.9	190.9	191.7	192.6
13	Nonmetallic mineral products	186.3	189.5	189.6	192.4	193.6	195.1	198.6	198.9	200.4	201.5	202.4	204.2	205.3	205.6
13-11	Flat glass	150.0	152.7	152.7	152.9	159.6	159.6	159.6	159.8	161.6	160.0	161.1	161.1	162.5	164.0
13-2	Concrete ingredients	186.7	189.1	189.5	194.0	194.3	195.4	198.4	198.9	199.1	199.8	200.1	200.3	200.7	200.8
13-3	Concrete products	180.1	182.4	183.0	187.2	187.9	188.4	189.9	190.5	190.9	192.8	193.5	194.0	195.0	195.4
13-4	Structural clay products excluding refractories	163.5	168.2	168.8	170.1	168.4	170.7	177.5	174.2	180.2	183.8	184.5	185.7	187.8	185.1
13-5	Refractories	184.0	193.0	192.9	193.1	193.2	193.2	193.3	194.9	196.1	197.0	198.3	206.9	208.9	210.0
13-6	Asphalt roofing	238.3	239.4	234.8	230.5	230.5	243.1	243.1	243.1	246.2	253.5	253.5	267.1	275.2	275.2
13-7	Gypsum products	154.4	160.1	160.1	160.8	162.7	164.0	172.2	175.9	187.1	186.6	189.8	193.7	201.6	203.2
13-8	Glass containers	195.4	202.2	202.2	202.0	202.0	202.0	218.1	218.3	218.3	218.3	218.3	218.3	218.8	218.8
13-9	Other nonmetallic minerals	232.5	235.2	235.0	240.7	241.4	245.3	247.9	247.8	250.4	251.6	253.7	257.6	256.0	256.0
14	Transportation equipment[4]	151.1	156.2	157.0	157.1	157.2	158.4	158.7	159.0	159.4	159.5	160.6	161.4	[1]167.9	168.0
14-1	Motor vehicles and equipment	153.8	159.2	159.5	159.2	159.4	160.7	161.0	161.3	161.8	161.6	163.1	163.8	[1]170.8	170.6
14-4	Railroad equipment	216.7	222.8	223.3	227.9	227.9	230.0	231.1	231.1	232.0	234.2	235.2	235.2	238.7	238.7
15	Miscellaneous products	153.7	156.1	157.0	160.2	160.6	161.0	162.5	163.1	163.5	163.8	164.2	166.5	168.4	168.9
15-1	Toys, sporting goods, small arms, ammunition	150.0	151.0	151.1	153.8	154.1	154.5	154.2	154.4	154.8	155.1	155.6	155.3	156.5	156.7
15-2	Tobacco products	183.0	172.2	172.3	174.7	174.8	174.6	175.1	175.3	175.3	175.7	175.8	189.6	189.6	189.6
15-3	Notions	162.3	165.3	165.7	169.9	172.4	172.4	172.4	172.4	172.4	172.6	172.9	172.9	172.9	172.8
15-4	Photographic equipment and supplies	136.2	137.2	139.3	138.2	138.4	138.5	137.9	139.9	140.4	141.2	141.0	140.6	140.7	140.7
15-9	Other miscellaneous products	152.9	151.5	152.7	160.2	160.9	161.9	167.2	167.3	167.1	167.0	167.5	167.7	173.1	174.1

[1]December 1975 = 100
[2]December 1969 = 100
[3]December 1970 = 100
[4]December 1968 = 100.

FIGURE B-1 (continued) Wholesale Price Index

36. Effective wage adjustments going into effect in major collective bargaining units, 1971 to date
[In percent]

Sector and measure	Average annual changes						Average quarterly changes							
	1971	1972	1973	1974	1975	1976	1975	1976				1977p		
							IV	I	II	III	IV	I	II	III
Total effective wage rate adjustment, all industries	9.2	6.6	7.0	9.4	8.7	8.1	1.5	1.3	2.7	2.5	1.5	1.2	2.8	2.8
Change resulting from—														
Current settlement	4.3	1.7	3.0	4.8	2.8	3.2	.6	.3	1.3	.8	.9	.3	.9	1.2
Prior settlement	4.2	4.2	2.7	2.8	3.7	3.2	.5	.6	1.2	1.0	.4	.5	1.4	1.0
Escalator provision	.7	.7	1.3	1.9	2.2	1.6	.4	.4	.2	.7	.3	.3	.6	.4
Manufacturing	8.0	5.6	7.3	10.3	8.5	8.5	1.6	1.4	2.2	2.5	2.4	1.2	2.8	2.5
Nonmanufacturing	10.3	7.4	6.7	8.6	8.9	7.7	1.5	1.2	3.1	2.6	.8	1.1	2.8	2.6

NOTE: Because of rounding and compounding, the sums of individual items may not equal totals.

FIGURE B-2 Wage Rate Adjustments

Monthly Labor Review published by the U.S. Department of Commerce (see Figures B-1 and B-2). Separate inflation rates should be developed for Refined Petroleum Products, (Code 057, Fuel and Oil) Motor Vehicles and Equipment, (Code 141, Maintenance Parts and Salvage Value), and Labor Wage Rates. The transit authority's union labor contract may provide a more appropriate wage inflation factor, depending on the form of the contract and its effective dates. The general equation for calculating inflation index is:

Inflation Index (I) =

$$\frac{\text{Price Index (Current Month)} - \text{Price Index (One year ago)}}{\text{Price Index (One year ago)}}$$

For Petroleum Products:

$$I_p = \frac{313.4 - 285.8}{285.8}$$

$$= .097 \text{ or } 9.7 \text{ percent}$$

For Motor Vehicles and Equipment:

$$I_v = \frac{170.6 - 159.2}{159.2}$$

$$= .072 \text{ or } 7.2 \text{ percent}$$

For labor wage rates, percent change, I_l is reported directly. The recent annual rate of 8.5 percent is found by adding the last four quarterly rates.

Discount Rate — The discount rate, i_d, is used to compute the net present worth of a future expenditure. For purposes of life-cycle cost analysis, the recommended discount rate is the current U.S. Treasury borrowing cost (interest rate) for obligations with a maturity approximately the same as the useful life of the vehicles being evaluated. This information can be found in regular financial publications, such as The Wall Street Journal (see Figure B-3). In this example, the average yield (i.e., interest rate), for Treasury Bonds and Notes with maturity ranging from 5 to 7 years, is 7.8% (Note that, in this instance, using comparable recent references, the inflation rate for two of the major categories of costs, fuel and labor, exceeds the discount rate.)

Adjustment Factors — The inflation factors to be applied to each year's costs are calculated by the formula:

$$\text{Inflation Factor (f)} = (1 + I)^n$$

where: I = decimal rate of change, and
n = future year - current year

The discount factor is developed in the same manner, but instead of multiplying, the quantity to be discounted is divided by the factor. Table B-4 shows the annual factors for inflation and discount using the rates, I_p = 9.7%, I_v = 7.2%, I_l = 8.5% and i_d = 7.8%.

Table B-4. Inflation and Discount Factors

	Inflation			Discount
Year	Commodities	Parts	Labor	
1	1.000	1.000	1.000	1.000
2	1.097	1.072	1.085	1.078
3	1.203	1.149	1.177	1.162
4	1.320	1.232	1.277	1.253
5	1.448	1.321	1.386	1.350
6	1.588	1.416	1.504	1.456

Table B-5 shows the application of inflation factors to all operating cost categories and to salvage values. The inflated annual costs in this table represent the best estimate of the actual outlay (or receipt) in each of the future years. The present worth of that outlay is shown in Table B-6, Discounted Amounts of Operating Costs and Salvage Value. (In Table B-6, the inflated amount is divided by the factor for discounting, whereas, in the Table B-5 the amount in current dollars was multiplied by the factor for inflation.)

Government, Agency and Miscellaneous Securities

Monday, April 3, 1978

Over-the-Counter quotations; source on request.

Decimals in bid-and-asked and bid changes represent 32nds; 101.1 means 101 1/32. a-Plus 1/64. b-Yield to call date. d-Minus 1/64. n-Treasury notes.

Treasury Bonds and Notes

Rate	Mat. Date		Bid	Asked	Bid Chg.	Yld.
[illegible]	1978	Apr n	99.29	99.31	....	6.76
[illegible]	1978	May n	99.31	100.3	....	6.10
[illegible]	1978	May n	100.3	100.6	....	5.90
[illegible]	1978	May n	100	100.4	....	6.15
[illegible]	1978	Jun n	99.31	100.3	....	6.26
[illegible]	1978	Jul n	99.30	100	− .1	6.79
[illegible]	1978	Aug n	100.6	100.10	....	6.60
[illegible]	1978	Aug n	100.19	100.23	....	6.65
[illegible]	1978	Aug n	99.25	99.29	....	6.82
[illegible]	1978	Sep n	99.18	99.22	....	6.90
[illegible]	1978	Oct n	99.8	99.12	....	7.01
6s.	1978	Nov n	99.8	99.12	....	7.06
[illegible]	1978	Nov n	99.2	99.6	+ .1	7.04
[illegible]	1978	Dec n	98.17	98.21	+ .1	7.14
[illegible]	1978	Dec n	100.17	100.21	....	7.20
[illegible]	1979	Jan n	98.25	98.29	....	7.26
7s.	1979	Feb n	99.24	99.28	....	7.15
[illegible]	1979	Feb n	98.22	98.26	....	7.26
6s.	1979	Mar n	98.22	98.26	− .1	7.27
[illegible]	1979	Apr n	98.13	98.17	....	7.33
[illegible]	1979	May n	100.14	100.18	− .1	7.34
[illegible]	1979	May n	98.16	98.20	....	7.39
[illegible]	1979	Jun n	98.12	98.16	− .1	7.41
[illegible]	1979	Jun n	100.8	100.12	− .1	7.43
[illegible]	1979	Jul n	98.12	98.16	− .1	7.46
[illegible]	1979	Aug n	98.13	98.17	− .1	7.40
[illegible]	1979	Aug n	99.3	99.7	− .1	7.49
[illegible]	1979	Aug n	98.23	98.27	....	7.51
[illegible]	1979	Sep n	98.21	98.25	− .1	7.51
[illegible]	1979	Sep n	101.8	101.12	....	7.51
[illegible]	1979	Oct n	99.13	99.17	− .1	7.57
[illegible]	1979	Nov n	97.29	98.1	....	7.57
[illegible]	1979	Nov n	98.19	98.23	− .1	7.48
7s.	1979	Nov n	99.2	99.6	− .1	7.54
[illegible]	1979	Nov n	99.7	99.11	− .1	7.55
[illegible]	1979	Dec n	99.5	99.9	− .1	7.57
[illegible]	1979	Dec n	99.25	99.29	+ .1	7.56
[illegible]	1980	Jan n	99.22	99.26	....	7.65
4s.	1980	Feb	94.5	94.13	+ .2	7.26
[illegible]	1980	Feb n	97.31	98.3	+ .1	7.61
7.65s.	1980	Feb n	99.26	99.30	....	7.66
[illegible]	1980	Mar n	99.21	99.23	+ .1	7.66
[illegible]	1980	Mar wi	99.20	99.22	....	7.68
[illegible]	1980	May n	98.15	98.19	− .1	7.61
[illegible]	1980	Jun n	99.26	99.30	− .2	7.66
[illegible]	1980	Aug n	97.28	98	....	7.69
9s.	1980	Aug n	102.26	103.2	− .1	7.56
[illegible]	1980	Sep n	98.3	98.7	....	7.68
[illegible]	1980	Nov	91.6	91.14	....	7.15
[illegible]	1980	Nov n	98.16	98.20	....	7.72
[illegible]	1980	Dec n	95.18	95.22	....	7.65
7s.	1981	Feb n	97.30	98.2	− .2	7.77
[illegible]	1981	Feb n	[illegible]	99	− [illegible]	[illegible]
[illegible]	1981	[illegible]		[illegible]		
[illegible]	[illegible]	[illegible] n	97.17	[illegible].21	− .1	7.77
[illegible]	1981	May n	98.26	98.30	− .2	7.77
[illegible]	1981	May n	99.3	99.5	− .1	7.80
[illegible]	1981	Jun n	96.30	97.2	....	7.79
7s.	1981	Aug	98.4	98.8	− .2	7.60
[illegible]	1981	Aug n	99.15	99.23	....	7.73
[illegible]	1981	Sep n	96.24	96.28	....	7.79
7s.	1981	Nov n	97.13	97.17	....	7.80
[illegible]	1981	Nov n	97.27	97.30	− .2	7.77
[illegible]	1981	Dec n	97.30	98	....	7.88
[illegible]	1982	Feb n	94.6	94.14	....	7.82
[illegible]	1982	Feb	94.30	95.14	....	7.76
[illegible]	1982	Mar n	99.30	100	....	7.87
7s.	1982	May n	96.29	97.1	− .1	7.86
8s.	1982	May n	100.14	100.22	....	7.80
[illegible]	1982	Aug n	100.26	100.30	+ .1	7.86
[illegible]	1982	Nov n	96.30	97.2	− .1	7.90
[illegible]	1982	Nov n	99.29	100.1	....	[illegible]
8s.	1983	Feb n	100.9	100.13	....	[illegible].90
[illegible]	1983	May n	99.20	99.22	+ .2	[illegible].94
[illegible]	1978-83	Jun	81.30	82.14	....	[illegible]
7s.	1983	Nov n	96.4	96.12	+ .2	[illegible].81
[illegible]	1984	Feb n	96.17	96.21	+ .2	[illegible].98
[illegible]	1984	Aug	91.30	92.14	− .2	7.91
[illegible]	1984	Aug n	96.14	96.18	+ .2	7.95
8s.	1985	Feb n	99.27	99.29	+ .1	8.01
[illegible]	1985	May	77.12	77.28	....	7.39
[illegible]	1975-85	May	81.22	82.22	....	7.43
[illegible]	1986	May n	98.26	99.2	+ .2	8.03
8s.	1986	Aug n	99.21	99.29	+ .1	8.01
[illegible]	1986	Nov	88.14	89.14	....	7.80
[illegible]	1987	Nov n	98.24	98.28	+ .2	8.10
[illegible]	1990	Feb	75.4	76.4	− .4	[illegible].40
[illegible]	1990	May	[illegible].20	101.4	....	[illegible].10
[illegible]	1987-92	Aug	76.4	77.4	− .4	[illegible].77
[illegible]	1992	Aug	92	92.8	....	[illegible].18
4s.	1988-93	Feb	75.24	76.24	− .8	[illegible].46
[illegible]	1993	Feb	88.18	89.18	− .8	7.96
[illegible]	1993	Feb	97	97.4	....	8.21
[illegible]	1988-93	Aug	94.12	95.12	+ .6	8.03
[illegible]	1989-94	May	75.24	76.24	− .2	6.47
3s.	1995	Feb	75.6	76.6	− .2	5.13
7s.	1993-98	May	89.16	90.16	− .16	7.95
[illegible]	1998	Nov	75.8	75.24	....	5.48
[illegible]	1994-99	May	101.17	102.1	− .1	8.27
[illegible]	1995-00	Feb	95.18	95.26	+ .2	8.29
[illegible]	1995-00	Aug	100.7	100.15	+ .3	8.32
8s.	1996-01	Aug	96.21	96.29	+ .3	8.31
[illegible]	2000-05	May	99.1	99.9	+ .2	8.32
[illegible]	2002-07	Feb	92.20	92.28	+ .4	8.29
[illegible]	2002-07	Nov	95.8	95.16	+ .2	8.29

U.S. Treas. Bills

Mat	Bid (Discount)	Ask (Discount)	Mat	Bid (Discount)	Ask (Discount)
4- 4	6.56	6.10	7-25	6.56	6.48
4- 6	6.49	6.11	7-27	6.55	6.47
4-13	6.49	6.07	8- 3	6.57	6.49
4-20	6.34	6.34	8-10	6.60	6.52
4-27	6.66	6.52	8-17	6.63	6.54
5- 2	6.44	6.28	8-22	6.65	6.57
5- 6	6.42	6.26	8-24	6.66	6.60
5-11	6.42	6.26	8-31	6.67	6.59
5-18	6.42	6.26	9- 7	6.66	6.60
5-25	6.42	6.26	9-14	6.67	6.61
5-30	6.42	6.26	9-19	6.68	6.62
6- 1	6.38	6.26	9-21	6.70	6.64
6- [illegible]	[illegible]	6.26	[illegible]	6.60	[illegible]

FNMA Issues

Rate	Mat	Bid	Asked	Yld
7.15	6-78	100	100.3	6.49
7.45	6-78	100.1	100.5	6.45
7.15	9-78	99.30	100.2	6.97
7.45	9-78	100.2	100.6	6.97
6.75	12-78	99.14	99.22	7.31
8.95	12-78	100.28	101.4	7.28
7.25	3-79	99.28	100.4	7.24
7.85	6-79	100	100.16	7.39
9.80	6-79	102.4	102.20	7.42
6.40	9-79	98	98.16	7.52
7.50	9-79	99.28	100.12	7.51
8.50	10-79	100.28	101.12	7.52
6.55	12-79	97.28	98.12	7.50
7.75	1-79	[illegible]	[illegible].8	[illegible]

1983-85 Maturity, Average Yield 7.8%

FIGURE B-3 Interest Rates on Treasury Notes
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Table B-5. Inflated Operating Costs and Salvage Value

Year & Cost Category	Factor	Vehicle X Current	Vehicle X Inflated	Vehicle Y Current	Vehicle Y Inflated	Vehicle Z Current	Vehicle Z Inflated
First Year							
Labor	1.0	$1,589	$1,589	$1,718	$1,718	$3,050	$3,050
Parts	1.0	765	765	1,305	1,305	1,675	1,675
Commodities	1.0	2,365	2,365	2,270	2,270	3,035	3,035
Sub-Total		4,719	4,719	4,293	4,293	7,760	7,760
Second Year							
Labor	1.085	$1,440	$1,562	$ 580	$ 629	$2,855	$3,098
Parts	1.072	792	852	1,350	1,447	1,675	1,796
Commodities	1.097	2,365	2,594	2,270	2,490	3,035	3,329
Sub-Total		4,600	5,008	4,200	4,566	7,565	8,223
Third Year							
Labor	1.177	$1,495	$1,562	$ 580	$ 629	$2,855	$3,098
Parts	1.072	795	852	1,350	1,447	1,675	1,796
Commodities	1.097	2,365	2,594	2,270	2,490	3,035	3,651
Sub-Total		4,685	5,552	4,265	5,040	7,760	9,163
Fourth Year							
Labor	1.277	$1,550	$1,979	$ 620	$ 792	$3,105	$3,965
Parts	1.232	855	1,053	1,440	1,774	1,815	2,236
Commodities	1.320	2,365	3,122	2,270	3,287	3,035	4,395
Sub-Total		4,770	6,154	4,330	5,853	7,955	10,596
Fifth Year							
Labor	1.386	$1,605	$2,225	$ 640	$ 887	$3,230	$4,477
Parts	1.321	885	1,169	1,485	1,962	1,885	2,490
Commodities	1.448	2,365	3,425	2,270	3,287	3,035	4,395
Sub-Total		4,855	6,819	4,395	6,136	8,150	11,362
Sixth Year							
Labor	1.504	$1,660	$2,497	$ 660	$ 993	$3,355	$5,046
Parts	1.416	915	1,296	1,530	2,166	1,955	2,768
Commodities	1.588	2,365	3,756	2,270	3,605	3,035	4,820
Sub-Total		4,940	7,549	4,460	6,764	8,345	12,634
Salvage Value	1.416	$12,500	$17,700	$11,400	$16,142	$7,800	$11,045

Table B-6. Discounted Amounts of Operating Costs and Salvage Value

Year	Discount Factor	Vehicle X		Vehicle Y		Vehicle Z	
		Infl'd	Disc'd	Infl'd	Disc'd	Infl'd	Disc'd
First	1.0	$4,719	$4,719	$4,293	$4,293	$7,760	$7,760
Second	1.078	5,008	4,646	4,566	4,236	8,223	8,628
Third	1.162	5,552	4,778	5,040	4,337	9,163	7,886
Fourth	1.253	6,154	4,911	5,562	4,439	10,207	8,146
Fifth	1.350	6,819	5,051	6,146	4,553	11,362	8,416
Sixth	1.456	7,549	5,186	6,764	4,646	12,634	8,677
Total All Years		$35,801	$29,290	$32,353	$26,504	$59,349	$48,513
Salvage Value	1.456	$17,700	$12,157	$16,142	$11,087	$11,045	$ 7,586

Availability

Fleet availability calculations are based on the average frequency with which any one vehicle is out of service or unusable (i.e., the complement of availability), and the probability that several vehicles will be unavailable at one time. Vehicle availability for small buses usually ranges from 80 to 95 percent of peak demand time, but the probability that one or two vehicles in a small fleet will be out of service at any given time is much higher. The cumulative probability that several vehicles will be out of service at one time is a significant factor if the fleet is small (less than 50 vehicles), and if the average proportion of time that individual vehicles are unusable is comparatively high (i.e., greater than 10% of the time).

Performance data assumed for the vehicles being analyzed in this example are shown in Table B-7.

Table B-7. Availability Factor Vehicles

	Vehicle X	Vehicle Y	Vehicle Z
Total Peak-Demand Hours Reported	4320	7295	5160
Peak-Hours when Vehicle was Unusable	456	504	642
Proportion of Time Vehicle is Unusable	.106	.069	.124
Proportion of Time Vehicle is Available	.894	.931	.876

For this LCC example, it is assumed that the 10 vehicle peak-demand must be met 95 percent of the time. This is equivalent to saying that 10 or more vehicles must be available for use on 19 days out of 20 on the average, or that on only 1 day out of 20 there can be fewer than 10 vehicles in service. For a 12 vehicle fleet, this means that the cumulative probability of having zero, one, or two vehicles unusable cannot be less than 0.95.

For various fleet sizes and average down-time of individual vehicles, the probability that at least some specific number will be in service can be determined from standard tables of cumulative binomial probability found in various statistical texts and reference books. Selected values of Cumulative Binomial Probability are shown in Table B-8.

Table B-8. Probability of Ten or More Usable Vehicles

Fleet Size	Average Vehicle Availability	Probability of 10 or More Available
12	.94	.968
	.93	.953
	.92	.935
13	.90	.966
	.89	.954
	.88	.939
	.87	.922
14	.88	.980
	.87	.973
	.86	.964
	.85	.953
	.84	.941

The vehicle availability calculated in Table B-7 is used as an entry to Table B-8. For Vehicle X with an average availability of .894, and a 12-vehicle fleet, 10 vehicles would be usable much less than 95 percent of time, but with 13 vehicles in the fleet, 10 would be usable about 95.9 percent of the time. For Vehicle Y, availability is .931 and, with a 12-vehicle fleet, 10 would be usable about 95.5 percent of the time. For Vehicle Z, with an average availability of .876, 10 vehicles would be usable from a 13-vehicle fleet about 93.2 percent of the time and from a 14-vehicle fleet about 97.8 percent of the time. Therefore, to satisfy the 95 percent criterion, a fleet of 13 will be required with Vehicle X, 12 with Vehicle Y, and 14 with Vehicle Z.

To adjust the life-cycle costs, the costs of the additional vehicles are divided by 12 (the basis fleet size requirement) and added to the calculated life-cycle cost. The costs incurred are those related to numbers of vehicles and not mileage costs (since total fleet mileage will be the same regardless of size of fleet). In this example, per vehicle costs include initial price, wear-in maintenance costs, and the credit for salvage value (adjusted for inflation and discount). See Table B-9.

Table B-9. Adjustment for Fleet Size

	Vehicle X	Vehicle Y	Vehicle Z
Fleet Size Requirement	13	12	14
Number of Additional Vehicles	1	0	2
Initial Price[1]	$53,500	$36,800	$34,200
Maintenance 'wear-in' Costs[2]	204	158	320
Salvage Value[3]	(12,157)	(11,087)	(7,586)
Total 'per vehicle' Costs	41,547	25,871	26,934
Additional Cost[4]	41,547	---	53,868
LCC Adjustment[5]	3,462	---	4,489

1. From Table B-3.
2. From Table B-1.
3. From Table B-5.
4. Total 'per vehicle' costs times number of additional vehicles.
5. Additional Cost divided by Basic Fleet Size (12).

Total Life-Cycle Costs

The total LCC of each of the three vehicles can now be calculated by adding (algebraically) the initial price, operating costs (adjusted for inflation and discount), salvage value (also adjusted) and adjustment for fleet size (or vehicle availability), as shown in Table B-10.

In this example, Vehicle Y shows a clear superiority in terms of life-cycle costs. The low life-cycle cost for this vehicle results from low operating costs, high reliability or availability (a 12-vehicle fleet is sufficient), and low net depreciation of the vehicle (i.e., initial price, less residual or salvage value).

Table B-10. Life-Cycle Costs Summary

Cost Item	Vehicle X	Vehicle Y	Vehicle X
Initial Purchase Price[1]	$53,500	$36,800	$34,000
Operating Costs[2]	29,290	26,504	48,513
Salvage Value[2]	(12,157)	(11,087)	(7,586)
Fleet Size Adjustment[3]	3,462	---	4,489
Total LCC per Vehicle	$74,095	$52,217	$79,616

1. From Table B-3.
2. From Table B-5.
3. From Table B-9.

APPENDIX C

GLOSSARY

Community Circulation	a mode of operation for transit in which vehicles follow fixed routes within a limited urban district, usually at high frequency.
Conventional Urban Transit Coach	a passenger bus, 35' to 40' in length, designed and constructed for local fixed-route transit service in urban communities.
Demand Responsive	a mode of operation for transit in which vehicle schedules and routes are determined by current requests for service.
Directed Procurement	a procurement action in which the distribution of the request for proposals is limited to one or more preselected sources.
Discounted Value	the net present value of future disbursements or receipts.
Downtime	time that a piece of equipment is inoperable because of defects in the equipment.
Fleet-Size Requirement	the number of vehicles needed to provide a specified service, including allowances for spare vehicles.
Initial Unit Price	the cost of purchasing a single piece of new equipment.
Life-Cycle Costing	determination of relative economic value of equipment, materials or methods by aggregating and comparing the total costs associated with initial acquisition and installation, operation and maintenance, and removal or disposal at the end of the useful life (See Total Cost of Ownership).
Low-Bid-Price	proposal evaluation criterion, in conventional procurement practice, selection based on lowest initial unit price of equipment, materials or services.
Maintenance	in public transit, the repair, servicing and cleaning of vehicles, equipment and facilities.
Mode	in transit operations, the type of system (e.g., bus, light rail) or operation (e.g., demand responsive, line haul) by which passenger transportation is provided.

Net Present Value	the sum of money that, if invested now at interest, would have a specified value at a future date.
Operation	in public transit, the scheduling, dispatching, control, and operation of buses for the purpose of carrying passengers. Operating costs include drivers and supervisory personnel and may be defined to include the costs of preparing the vehicle for operation.
Peak Demand Time	the period of time when the greatest demand for equipment or services occurs.
Performance Specification	a form of specification in which the conditions and requirements of operation are defined, as opposed to detailed specifications in which design, component dimensions, material characteristics and similar information are defined.
Responsiveness to Specifications	tender of equipment, materals, or services that are in compliance with the provisions of the specifications defining the desired purchase.
Revenue Service Operation	in the transit industry, regular public operation of a vehicle to transport paying passengers.
Salvage Value	the market value (or, if the vehicle is to continue in service, the residual value) of a vehicle or other equipment or materials, at the end of a specified period of use.
Service Environment	in transit, the conditions, such as terrain, climate and traffic, under which a vehicle operates.
Service Requirements	in transit, parameters, such as operating miles and speed, acceleration, stopping frequency, and load capacity, that define the service a vehicle performs.
Small Transit Bus	a passenger vehicle, less than 35' in length, operated in public transit service.
Total Cost of Ownership	net aggregate cost of acquiring and operating or using equipment or materials during their useful life or a prescribed period of service.

Vehicle Availability	the portion of total time, or of peak-demand time, that a vehicle is operable and either in service or ready to perform service.
Wear-in	a period of use immediately after purchase of new equipment when the incidence of failure is high due to undetected flaws in components and improper assembly. Also, referred to as breaking-in, running-in, or burn-in.

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