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LIFE-CYCLE COST PROCUREMENT PROCEDURES FOR ADVANCED-DESIGN BUSES (DEVELOPMENT AND TEST APPLICATION)

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ADVANCED MANAGEMENT SYSTEMS, INC.

May 30, 1980
Final Report

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16. Abstract
This report reflects UMTA's efforts to assist the grantees to comply with the DOT FY 1980 Appropriations Act requirement that contracts for the acquisition of rolling stock, including urban buses, and that be awarded only after consideration of performance, standardization, life-cycle costs, etc., in addition to initial capital costs. A key to this assistance is presented in this report, namely - a set of acceptable, workable life-cycle costing procedures and guidelines to be used by the bus manufacturers and the grantees in life-cycle procurements. The authors foresee added benefits to be derived from applying the approaches developed in this study to "live" procurements.

This study aims to develop the life-cycle cost tools, guidelines, and procedures applicable to the bus industry and to apply the principles of life-cycle costing to the real-life environment of Advanced Design Bus (ADB) purchases. Tests were conducted by two transit properties--Phoenix Transit Authority (Phoenix, Arizona), and the Regional Transportation Authority (Chicago, Illinois). The parallel, nonbinding life-cycle cost procurements of ADB by the two transit operators demonstrated that life-cycle costing, when used as a procurement tool, is a viable alternative to the current low-bid acquisition of urban buses. The tests further showed that life-cycle cost procurement provides the grantees with the data necessary to make a more cost-effective purchase; it also provides the manufacturers an incentive to modify their bus designs to achieve better quality at a lower total cost of ownership.

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Life-Cycle Costing, Advanced Design Bus, Guidelines, Procurement, Operations and Maintenance, Transit Properties, Requirements, Bus, Accounting

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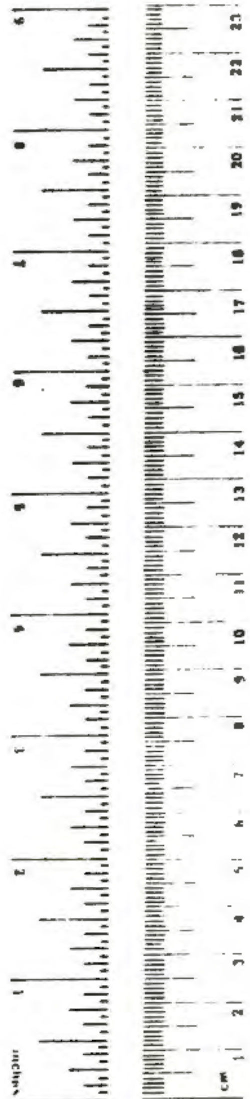
METRIC CONVERSION FACTORS

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
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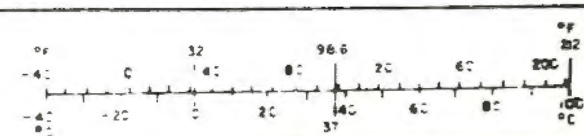
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FOREWORD

This study is a continuation of work begun by AMS to introduce life-cycle costing as a key element in the procurement decision. A previous report developed the feasibility of using life-cycle costing by concentrating upon "can and should it be done?". This study, in turn, focuses attention upon impelementing life-cycle cost procedures in two ways. AMS began by developing and refining a kit of procedures, guidelines, lists, et al. Then the kit was tested, as buses were being purchased, to evaluate the contents of the kit. The results lend further support to the wisdom of applying life-cycle costing to bus procurements.

Further improvements in the use of life-cycle costing techniques will be enhanced by the requirements of the FY 1980 Transportation Appropriations Act, which calls for consideration of life-cycle costing in bus procurements. Therefore, AMS foresees added benefits to be derived from applying the approaches developed in this study to "live" procurements.

ADVANCED MANAGEMENT SYSTEMS, INC.

Harry R. Kain, President

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INTRODUCTION

Advanced Management Systems (AMS), Inc., has conducted this study for the Urban Mass Transportation Administration (UMTA) within the scope of the two tasks assigned in the U. S. Department of Transportation's contract DOT-UT-70067. Task I included development of: (a) operating and maintenance (O&M) cost factors for use in life-cycle cost (LCC) evaluation, (b) types of engineering analyses to be used by manufacturers in support of their LCC data, (c) minimum operating and maintenance cost records essential for the property's participation in the LCC feasibility study, and (d) the engineering support necessary for adequate LCC evaluation by the property.

Task II included assisting: (a) the bus manufacturers in identifying, quantifying, and supporting their estimates of cost impact of the Advanced-Design Bus (ADB) design changes on O&M costs; (b) the properties in identifying, measuring, and evaluating their current O&M cost experience; (c) the properties in evaluating the manufacturers' design changes in terms of their acceptability on the basis of the support furnished and their value to the properties; and (d) the properties in projecting their adjusted costs over the life of the bus to determine the life-cycle cost of each of the competitors' buses.

In performing these tasks AMS worked closely with UMTA, the selected bus properties, and the bus manufacturers. UMTA was attuned to the progress of the study through meetings, briefings, and reports. In addition, a list of properties (prospective candidates for the test) which had prospects of procuring the ADB was developed. (See Appendix A.) From this list, the Phoenix Transit Administration (Phoenix, Arizona) and the Regional Transportation Authority (Chicago, Illinois) were selected for the test. This selection was based upon the dissimilarities between the two properties rather than upon any commonalities. The manufacturers of the ADB were Coach and Truck Division, General Motors, and Flxible Division, Grumman Corporation.

The study and the resultant report were structured to develop and present clearly discernible points which could fit into two categories. The first of these was the development of a bank of knowledge about the bus in conjunction with LCC procedures. This would include pertinent characteristics of LCC applicable to the ADB, common reference points for bus operator and bus manufacturer, bus features, tests, cost factors, and selected costs (cost drivers). The second area would include the test and evaluation, covering the rules of the game. Each of these points was covered in subsequent sections of the report.

LIFE-CYCLE COSTING APPLIED TO ADB PROCUREMENT

Current bus procurement practices allow the contract award to be made on the basis of the initial or delivered price of the bus. The LCC procedure furnishes the means of making this decision on the basis of total cost of ownership. It is often described as a common-sense approach to buying.

The mandate of the UMTA/AMS contract was to develop the life-cycle cost tools, guidelines, and procedures applicable to the bus industry and to apply the principles of life-cycle costing to the real-life environment of Advanced-Design bus purchases. This mandate required the reduction of life-cycle costing principles from the theoretical to the practical level for utilization as a bus procurement tool.

The success of life-cycle costing in the procurement of buses depends upon several factors. First, the property must have the ability to identify, measure, and evaluate the factors affecting its current operating and maintenance costs. Second, the bus manufacturers must demonstrate the ability to identify, quantify, and support their estimates of the cost impact which bus design changes will have on a property's operating and maintenance costs. Third, harmonious working relationships between the manufacturers and the properties must exist. An atmosphere of mutual trust, an open exchange of information, hard work, and a desire to make LCC techniques work are essential to the success of the LCC effort.

All participants in this study provided support and cooperation. AMS arranged for the properties' representatives to visit the plants of both manufacturers to discuss all facets of the LCC study. This afforded everyone involved the opportunity to discuss and agree upon: (1) the mechanics of life-cycle costing as applied to bus procurement, (2) the O&M cost factors to be included in life-cycle costing, (3) what the manufacturers need to know to make LCC succeed, and (4) the part AMS would play in assisting the properties and the manufacturers in this feasibility study.

Advanced Management Systems responded to the UMTA contractual mandate in seven well-defined steps, as follows:

- Designated the ADB specification as the LCC control document, thereby allowing easier identification of O&M costs and "cost drivers."

- Developed the minimum accounting records essential to LCC when used as a procurement tool.

- Specified the engineering analyses to be accomplished by the manufacturers.

- Established the guidelines for development and evaluation of the LCC data.

- Developed the LCC procurement procedures to be followed.

- Planned for the "parallel, nonbinding procurement" by each of the participating properties to test the feasibility of using LCC as a procurement tool.

ADB SPECIFICATION USED AS CONTROL DOCUMENT

An early requirement for making progress in any concerted effort is to establish an acceptable point of reference. AMS proposed that the UMTA-published ADB specification serve this purpose. This proposal was acceptable to all participants and provided the means to make progress in other areas.

This choice was a natural one for several reasons. The specification was the one document with which the participants were thoroughly familiar. The operators (purchasers) used it to specify the technical requirements for the buses they were buying. The manufacturers complied with it in the manufacture of their Advanced-Design Buses. During development of the specification, manufacturers and operators worked closely with UMTA in determining the acceptability of numerous specification requirements. AMS was confident that the participants' familiarity with the definitions, technical requirements, tests, and limitations would minimize the misunderstandings and disagreements normally attendant to studies of this type.

AMS used the ADB specification in identifying meaningful categories of O&M costs that contribute to bus life-cycle costs which can be reduced by technological improvements to the bus. The specification served as the source of tests that the manufacturers could use in establishing suitable support data for their life-cycle cost estimates of impact. The suggested design changes which could impact upon life-cycle O&M costs were worked up from the ADB specification and provided to the manufacturers. To maintain this element of control, the manufacturers and operators were instructed to use the ADB specification paragraph number as a reference in identifying or evaluating each cost category.

An early demonstration of the value of the specification as the control document was presented in defining the O&M costs covered by this study. Excluded from consideration were costs associated with drivers' wages, rents and insurance, maintenance and other costs of shop equipment, etc. In short, the O&M costs included were identified as those which were affected by the design of the bus. Future reference to O&M costs means design-related O&M costs.

Life-cycle costing serves as an incentive for the bus manufacturer to make design changes which will reduce the property's O&M costs. Therefore the areas of recurring costs which are directly affected by bus changes must be recognized as those included in: (1) scheduled and unscheduled maintenance, including preventive maintenance; (2) fuel and oil costs; and (3) tire costs. Initiative taken to change the bus design can impact directly on these costs. For the property, these areas become cost generators and, for tracking purposes, would be developed as shown in Appendix B, "Cost Elements."

Many opportunities occur for design changes which impact upon bus O&M costs. Appendix C, "Design Changes Which Affect Life-Cycle O&M Costs," shows 58 areas where costs can be affected. Although the desired outcome is to decrease total life-cycle costs, certain changes may result in increased costs. It should also be noted that standardization and ease of accessibility also play important roles in cost savings. Standardization can reduce the parts inventory costs, and improving accessibility can reduce maintenance labor costs.

Tracing the costs associated with the cost elements described above, the property would develop the total O&M costs associated with their fleet or a series of buses or an individual bus. Upon examination of these costs, it was learned that a small number (fewer than ten) accounts for approximately 75% of the O&M costs; these were identified as "cost drivers." They are treated more fully later in the study. (See Life-Cycle Cost Procurement Procedures and Guidelines," p. 9, and "Summary of Principal Gains from Test Application," p. 13.)

ACCOUNTING RECORDS

The listing of bus areas providing a potential for LCC improvements, as shown in Appendix C, is quite detailed. Accordingly, the cost-collection system must possess the characteristics which provide for the evaluation of detailed changes. AMS has concluded that life-cycle costing can be pursued if: (1) the accounting records possess detailed cost segregation; and (2) the accounts are oriented toward the technical specification and have the ability to summarize accounts by bus, series of buses, or the entire fleet. As the LCC procedures are refined (through changed bidding systems), the accounting records become a more valuable asset to the property. For example, as added ADBs enter the fleet, cost segregation for comparative purposes may allow the costs of the ADBs to be considered in the evaluation in any new procurement. In addition, it may become necessary or advantageous to require added "cost drivers" for evaluation purposes. The accounting records would provide the signal for these occurrences.

Detailed Cost Segregation

Design changes are normally made on a component of the bus. Maintenance is also performed on components of the bus. In addition, problems are identified with specific components such as faulty brakes, inoperative taillights, or unresponsive steering. Therefore, a detailed cost-collection (accounting) system provides several advantages. First, it permits costs to be accumulated against detailed segments of the bus, so that improvements in the high-cost items can be evaluated. Second, it allows comparison of costs on design changes at the detailed level. Finally, personnel skills can be oriented toward specific segments of the bus.

Breakdown Oriented toward Technical Specification

The technical specification is a description of the bus components (design or performance). The detailed cost breakdown should be aligned to that specification so that components, changes, costs, and cost comparisons of design changes can be traced in an orderly manner. Appendix B contains an illustration of a detailed breakdown which allows costs to be accumulated in segments which are oriented toward the specification. The desired breakdown should be consistent with the most detailed description available.

For example, using Appendix B, the "Structural Components and Finish" appearing in Column A consists of the Shell, Exterior, Interior, and Floor shown in Column B. The Exterior, in turn, consists of panels, rubrails, access doors, wheel housing, skirts, aprons, etc. Each of these is described in the specification and can be separated from the others, as can the costs of redesign and repair. Therefore, whenever the breakdown can be traced to Column C, the cost-collection system would be at the Column C level. This is not always practical, as in the case of Operating Equipment, where details in Column B are sufficient, or in the case of Fuel, Tires, and Oil, where the description in Column A is sufficient.

Summary of Accounts

The bus is made up of many components. Although it is valuable to have detailed cost accounts to allow analysis at the detailed level, a summary of such costs provides good support for decisionmaking on an overall basis. This summarization should be feasible on a bus basis to identify anomalies ("dogs") in the fleet. Summarization against a group of buses is also desirable to allow comparison between different bus procurements or manufacturers. Finally, the cost summarization should be available for the entire fleet, so that these costs can be compared to the overall costs experienced by the transit operator. (Implicit in these requirements is the suggestion that as the fleet grows larger there is a need for data-processing support to accounting. This leads to greater objectivity and emphasis toward assigning costs to the proper account.)

Because of the importance of O&M records in the development of life-cycle cost data, and because of the wide divergence in recordkeeping practices among the transit operators, AMS sought to obtain a good cross section of the data-collection practices. For these reasons AMS carefully selected two transit operators whose recordkeeping practices included, in one instance, a computerized system and, in the other, a manual system. AMS estimates that approximately 90% of the transit operators utilize manual recordkeeping.

ENGINEERING ANALYSES BY MANUFACTURERS

The engineering analyses performed by the manufacturers to project life-cycle cost savings will utilize the same types of tests used to demonstrate compliance of the bus with the requirements of the original ADB specification. The various tests and demonstrations required by the specification are identified in Appendix D. For ease of reference and categorization, Part 1 lists the various tests required; Part 2 shows the maintenance tasks, times, and skills required; and Part 3 lists the standards and practices to which the bus manufacturers must adhere.

In the final analysis, all original tests should be reduced to report format for future reference; however, there must be some degree of participation by the transit operator when the tests are conducted. Design improvements in a specific component will follow the same testing approach. For example, if the specification requires a life of 5,000 cycles for an actuating device, the test that demonstrates a life of that magnitude would also be used to show that the life can be extended to a greater number, say 7,000 cycles. Similarly, a demonstration which shows that a bus feature meets a specification-required repair time of 30 minutes would also be used to prove a claim that an improved design will reduce repair time to, say, 15 minutes.

Therefore, the types of tests to be used in LCC analysis would be developed to show the results of design changes. Such testing implies a two-step procedure for LCC analysis. First, the design changes would be tested to determine the validity of the change (i.e., is it workable and acceptable). Once that requirement has been satisfied, the cost effects of that change would be analyzed in terms of their impact on O&M costs.

The following outline illustrates the types of tests which would be included in an LCC test and demonstration program:

a. Life-cycle demonstrations

Actuating devices would be subjected to a demonstration of the number of cycles that will identify the life of the mechanism. Examples of such devices include the door closing mechanism, windshield wipers, and kneeling features.

b. Functional tests

Functional tests would be applied to features of the bus which require a change in position (for example, on/off devices). These include forces which are applied by the driver or passengers, including those which perform a specific function after being activated. Examples of such devices include switches, steering mechanism, brakes, and air system. The purpose of this type of testing would be to demonstrate that the same function could be accomplished by the design. Subsequently, considering life-cycle costs, the claim that the components have longer life or perform multiple functions could be verified.

c. Visual tests

Visual tests would be used to confirm improvements in such features as the driver's eye range, reverse operation warning devices, chain and tire clearances, instrumentation and lighting arrangements, and signs.

d. Time demonstrations

The ADB specification requires that maintenance tasks such as those shown in Appendix D, Part 2, be performed within certain time limits and at a specific mechanical skill level. To meet the specification, these times and skills must be demonstrated to show increases or decreases in times or skill levels. In addition, there are other design-related features which must meet specific time requirements. Examples of these design features are: (1) the acceleration and deceleration requirements, (2) the requirements to meet the route profile, and (3) the times to assume the kneeling and, in turn, the normal positions.

e. Physical measurements

Certain features of the bus are designed with minimum or maximum dimensions. Accordingly, original delivery equipment and suggested design modifications must meet these dimensional requirements. Examples of such features are the floor height, chassis clearances, seat spacing, door openings, and window areas.

f. Gauged (metered) measurements

Special devices are required to conduct some of the tests. The results of these tests would be recorded, and a second test would be required for verification. Examples of these tests are: (1) air flow, (2) air filtration, (3) noise (exterior and interior), (4) the climate control system, and (5) illumination.

g. Impact tests

Impact tests may lead to destruction of the component being tested; therefore economics dictate that the number of such tests be limited. The original specification requires the conduct of certain crashworthiness tests, however, and any claimed improvement would require that the tests be duplicated. Examples of such tests would be those performed on the side panels, coach top, bumpers, passenger assists, doors, and seats.

h. Street tests

Verification of some features is not possible without "real-life" street demonstrations. Street tests would verify that the bus is a usable vehicle. During street tests some of the features which could be analyzed include: (1) problems of doors opening out; (2) kneeling feature problems of bus hitting curbs; (3) driver visibility (interior and exterior); and (4) the effectiveness of fenders, skirts, and splash aprons.

i. Adaptability demonstrations (service equipment)

A complete turnover of the bus inventory by a transit operator would be a rare exception. Generally, as new buses are acquired they are maintained in the same physical facilities and by the same mechanics as the rest of the fleet. It is therefore highly desirable that the existing facilities and personnel skills be adaptable to any new bus features. Adaptability of the existing equipment to design changes is a key factor for consideration. This is especially true of service equipment such as towing, jacking, washing, and cleaning equipment. If existing equipment can be used, this should be demonstrated; if new equipment is required, initial investment costs (for new service equipment) are also incurred, and some training becomes necessary. These additional costs must also be considered to derive accurate LCC estimates.

j. Supplier (vendor) tests

The bus manufacturer is not the original source of all materials and components incorporated into the bus. In certain respects he is very much like the transit operator when judging the acceptability of various materials. Appendix D, Part 3, shows various specifications and standards to be met at the supplier level. Corrosion, fire resistance, finishes, and material strengtbs are examples of areas in which the supplier would be responsible for the tests, and the manufacturer certifies the quality of the supplier's product.

TRANSIT OPERATOR ENGINEERING CAPABILITY AND SUPPORT

AMS has identified types of testing (analyses) to be performed by the bus manufacturer to assure compliance witb the bus specification and to provide evidence that a design or design improvement meets expectations. As previously noted, the results of any testing should be translated into written reports and made available to the customer.

AMS does not suggest that the bus manufacturers' reports should be accepted "after the fact" as evidence that the tests have been completed satisfactorily. The transit operator should become involved in the testing process by either complete or sample inspections of the testing operations.

Unlike the acceptance of the current (on-the-street) buses, the ADB specification is oriented toward performance. AMS found in the developing report (UMTA-VA-06-0039-76-1, dated July 9, 1976) that the current buses, irrespective of manufacturer, consisted of common-source components. The major differences were in the body and in the method of manufacture. Therefore it will be necessary for the transit operator to understand and evaluate the test results derived from each of the ten categories of manufacturers' tests, pages 6-8. Since the transit operator's staff may be limited in engineering capability (due to method of operation and necessity), outside help may be necessary.

AMS believes that acceptability or nonacceptability of the majority of the test categories previously noted can be determined on the basis of the know-how acquired from buying, operating, and maintaining buses. The transit operator's efforts should be focused primarily upon an understanding and evaluation of the following four areas:

a. Life-cycle demonstrations.

b. Gauged (metered) measurements.

c. Impact tests.

d. Supplier (vendor) tests.

Further, AMS recommends that the transit operator sample at least the first three categories and obtain the manufacturer's endorsement and acceptance of the supplier tests.

LIFE-CYCLE COST PROCUREMENT PROCEDURES AND GUIDELINES

The LCC procedures and guidelines developed by AMS, with sample worksheets and calculations, are presented in their entirety as Appendix E to this report. To allow for a greater understanding of the test application, the complete set of procedures follows, but the guidelines are highlighted and cross referenced with Appendix E as necessary. Reference to the use of "procedures" in subsequent sections of this report should be accepted as reference to these "procedures and guidelines."

Methodology

The following are step-by-step procedures to be followed by the transit operator and the bus manufacturers in a procurement of buses. They provide for the issuance of an invitation for bids (IFB) containing a requirement to submit a technical and price proposal in a single bid package. This bid package will consist of the following:

I. Technical Proposal

a. The request by the purchaser (operator) for a technical proposal from each of the potential bidders (bus manufacturers) will:

1. Identify the operator's current highest operating and maintenance cost factors (cost drivers). The following terms are suggested:

(a) Fuel in miles per gallon.

(b) Tire life in miles.

(c) Oil, lubricating, in miles per quart.

(d) For other cost drivers such as brakes, air conditioning, transmissions, etc., identify:

(1) Removal and replacement time and number of occurrences over the measured period.

(2) Repair time and frequency of repair over the measured period.

(3) Inspection and cleaning time and frequency over the measured period.

(e) Preventive maintenance intervals (3,000, 6,000, 10,000 miles) and maintenance hours and material cost.

These cost factors should be derived from the operator's actual fleet average O&M costs over two years, or as close to that period as possible. This is the "measured period" referred to above. These costs must include both labor and material costs. The factors selected should be the highest 75% of the operator's total O&M costs.

2. Require each bus manufacturer to provide the operator with a substantiated estimate of its ADB's LCC impact, positive or negative, on the operator's cost drivers, except for tire data, which the operator will obtain directly from the tire manufacturer. Substantiation or support of the estimates shall be based upon test results, experience data, comprehensive engineering analyses, or time study data.

b. The bus manufacturers will respond to the operator's IFB by:

1. Addressing each of the operator's high-cost O&M factors, excluding tires, and estimating the impact the corresponding features on their ADBs will have on these cost drivers.

2. Providing substantiation and support for their LCC estimates in the terms set forth in para. IA2 above.

II. Price Proposal

The price proposal will consist of the manufacturer's price for a delivered bus, including warranties.

Sequence of Events

I. Issuance of the IFB

II. Prebid Conference

a. There will be a need for a prebid conference to resolve technical questions prior to submission of technical and price proposals. This meeting will be held by the operator, with all potential bidders present.

b. The meeting will be scheduled by the operator and listed in the IFB.

c. The purpose of the prebid conference will be to:

1. Assure that the bidders understand the cost drivers identified in the IFB.

2. Assure the operator that he has a complete understanding of material that will be submitted by the bidders for those

specific cost drivers. The operator should limit his comments to expressions of understanding and should avoid remarks that could be construed as approval or disapproval.

3. Make every effort to assure that the proposals will be adequate, complete, and useful for evaluation by the operator.

4. Provide a record of all discussions, which will be made available to all bidders.

III. Submission of Bids

The bid will be submitted as a package consisting of a technical proposal and a price proposal, as described above.

IV. Evaluation and Price Proposal Adjustment

The operator will evaluate the bidders' technical proposals, including LCC tire data, in terms of acceptable, well-supported operating and maintenance costs over the buses' life of 500,000 miles each. The operator will then adjust each bidder's price proposal by the amount of the LCC impact on the O&M cost factors considered, multiplied by the number of buses being purchased. This adjusted figure represents the "cost of ownership," the sum total of the initial cost of the buses and the O&M costs for the selected cost factors over the life of the buses purchased.

V. Contract Award

Following the technical proposal evaluation and the price proposal adjustment, the operator makes the contract award to the bidder whose adjusted figure reflects the lowest cost of ownership.

Life-Cycle Cost Procurement Guidelines

The "guidelines" developed by AMS represented a set of ground rules for the conduct of the LCC study. These guidelines are presented in detail in Appendix E. Full recognition was given to the fact that LCC is new to the bus industry -- to manufacturers, operators, and UMTA. Certain ground rules applying to manufacturers and operators were established as "common guidelines." Examples of such "common guidelines" are the 500,000-mile bus life and the LCC cost factors. (See "Life-Cycle Cost Procurement Guidelines," page E-4, last paragraph.) The manufacturers used these guidelines for identifying technological design changes which affect follow-on O&M costs. The operators used the same guidelines in evaluating the impact of such changes on their current O&M costs.

The manufacturers were also given a specific set of rules applicable to their participation in the study. These rules included examples of the types of estimates of impact submissions and the measurable terms in which they should make their estimates. The ground rules also provided appropriate types of tests for the manufacturers to use in developing support for their estimates. (See Appendix E, page E-6.)

Similarly, the operators were provided guidelines for use in their participation in the study. These ground rules included such things as methods for evaluation of estimates of impact, the type of support required for the estimates, and the need to be alert to negative impacts on cost. For example, a new bus feature could have a positive effect by reducing an operator's current operating cost, but at the same time the added sophistication could have a negative impact by increasing current maintenance costs. (See Appendix E, page E-9.)

TEST OF LIFE-CYCLE COST PROCEDURES IN PARALLEL, NONBINDING PROCUREMENTS

The use of the procedures and guidelines described above was tested in "parallel, nonbinding procurement" of ADBs by two transit operators, Phoenix Public Transit Administration and Chicago Regional Transportation Authority. The approach was constructive in that it allowed two different buying techniques (low bid and LCC) to be applied simultaneously to the same real-life procurements. At the outset, it was understood clearly by all participants that the actual contracts would be awarded on the basis of the currently accepted low-bid acquisition method. It was also agreed that the life-cycle cost procurement test would in no way interfere with those awards.

Testing of the AMS LCC procedures was designed to provide answers to such important questions as:

- Are the necessary O&M cost data available at the transit operator's level?
- Can the operator retrieve and use the data properly in evaluating the ADB's impact on his current fleet cost experience?
- Can the manufacturers support their estimates of ADB impact adequately?
- Are the AMS LCC procedures and guidelines adequate?
- Can the operator's cost data be reconciled with the manufacturers' data for evaluation purposes?
- How do the LCC procedures affect the outcome (award)?

The test of the LCC technique was conducted, in accordance with the procedures developed previously, as follows:

1. The transit operators requested an LCC technical proposal from each of the two potential bidders in conjunction with their bid requests under the low-bid method. The price proposal in the low-bid package satisfied the requirement for a price proposal in the LCC procedures.

2. The operators provided the bus manufacturers with a list of those O&M cost factors which can be influenced by bus design changes. (See Chart 1, page 14.)

3. The manufacturers were also provided with each operator's current highest O&M cost drivers. (See Charts 2 and 3, pages 15 and 16.) The manufacturers were requested to advise the operators how their ADB O&M costs would impact, positively or negatively, their current O&M cost-driver experience.

4. One operator used a 103-bus fleet average cost experience over a two-year period for his O&M data base; the other operator used a 68-bus fleet average cost experience over a six-month period for his O&M data base.

5. The transit operators held prebid conferences, or technical clarification meetings, with the manufacturers. Some of the major points of discussion are shown on Chart 4, page 17.

6. The bus manufacturers provided the transit operators with their estimates of the ADB design impact on some of the operator's critical cost drivers. (See Charts 5-8, pages 18-21.)

7. The results of the operators' LCC evaluations of each manufacturer's ADB estimated impact over the life of the individual buses and the projected LCC impact over the life of the 37-bus buy by Operator 1 and the 205-bus buy by Operator 2 are shown on Charts 9-12, pages 22-25.)

8. The LCC adjustments to each manufacturer's price proposal are shown on Chart 13, page 26.

SUMMARY OF PRINCIPAL GAINS FROM TEST APPLICATION

The measure of success in a problem-solving study is the presentation of a tractable solution. The thrust of this study was the development of a set of procedures for implementing the LCC method in procurement of buses and test of those procedures in the real world. AMS feels that it is appropriate to review the principal features of their approach in order to evaluate its workability. This can be done by summarizing the administrative aspects, the cost drivers, and the evaluation data.

The administrative aspects of the AMS approach involved a meaningful series of steps toward reaching a decision. The specification-oriented cost collection system, potential bus design change areas, tests, and demonstrations provide a means of communicating between and among the participants during the procurement process. Therefore, the procedures and guidelines can more clearly and easily cover the ground rules affecting the exchange and submission of data.

Any data problem is greatly reduced by limiting the bid package to the

LCC Cost Factors

BODY
- Shell
  - Ext. & Applied Panels
  - Finish
  - Skirt Aprons
  - Floors
  - Steps & Stepwells
  - Wheel Housing
  - Passenger Doors
  - Service Compart. Serv. Doors
- Operating Components
  - Door Actuators
  - Windshield Wiper/Washer
  - Light Control & Instruments
  - Fare Box
  - Loading System
  - Signals
- Interior
  - Mirror
  - Passenger Seats
  - Driver Seats
  - Floor Covering
  - Panels & Bulkheads
  - Access Doors
  - Stanchions & Handrails
- Windows
  - Driver's Windows
  - Side Windows

CHASSIS
- Propulsion System
  - Engine
  - Cooling System
  - Transmission
  - Engine Accessories
  - Hydraulic Drive
- Final Drive
  - Rear Axle
  - Drive Shaft
- Suspension
  - Springs & Shocks
  - Front Axle
  - Kneeling
- Steering
- Brakes
  - Hubs & Drums
  - Air System
  - Friction Material
- General Chassis
  - Wheels
  - Fuel System
  - Bumper System
  - Frame
  - Electrical System
  - Electrical Components
- Climate Control
  - Heating
  - Air Conditioning
  - Ventilation
- Radio & Public Address System
  - Mobile Radio System
  - Public Address System

ROAD CALLS

PREVENTIVE MAINTENANCE
- Oil Change
- Tuneup
- Inspections
- Lubrications
- Cleaning & Washing

OPERATING FACTORS
- Fuel
- Tires
- Oil

Note: This breakdown is one that the properties currently visualize as related to their cost experience. It varies to some extent from the ADB-specification-oriented breakdown shown in Appendix B, which is preferred and recommended by AMS.

Chart 1

Operator 1 - O&M Cost Drivers

O&M Cost Drivers	Maintenance Events	Operator Time/ Cost Per Event	Frequency of Event (2-Year Period)
Maintenance Factors			
Exterior Skirt Panel	Remove and replace	540 minutes	36
Transmission Oil Cooler	Remove and replace	62 minutes	5
Air Conditioner			
Alternator and Fan Drive	Lubricate	9 minutes	291
Condenser Motor	Remove and replace	120 minutes	50
A/C Alternator	Remove and replace	160 minutes	50
A/C Blower Motor	Remove and replace	168 minutes	36
A/C Blower Motor Brushes	Remove and replace	168 minutes	36
Condenser Motor and Brushes	Remove and replace	120 minutes	50
Freon Compressor	Materials cost	$450.00	124
A/C Compressor	Remove and replace	300 minutes	124
Brakes	Inspect, measure & adjust 4 wheels	8 minutes	2,919

Operating Factors	Utilization Rate
Fuel	4.9 miles per gallon
Tires	70,000-mile average tire life

Chart 2

Operator 2 - O&M Cost Drivers

O&M Cost Drivers	Maintenance Events	Operator Time Per Event	Frequency of Event (6-Mo. Period)
Maintenance Factors			
Engine	Remove and replace	960 minutes	2
Transmission Oil Cooler	Remove and replace	65 minutes	Only 1 in 4 years
Preventive Maintenance	3,000-mile inspection	210 minutes	272
Brakes	Inspect, measure, adjust 4 wheels	8 minutes	544

O&M Cost Drivers	Utilization Rate
Operating Factors	
Fuel	4.8 miles per gallon
Tires	120,000 miles average tire life

Chart 3

Major Points of Discussion

at Prebid Conferences or Technical Clarification Meetings

- Reusable versus nonreusable transmission oil coolers
- Manufacturers' estimates of ADB fuel consumption rates
- Manufacturers' capability of responding to tire life on ADBs
- Effect of adjustable brake feature on brake lining life
- Doubling the maintenance on the dual air conditioning system's components
- The question of panel material equivalency between the current on-the street bus and the ADB
- The need for special tooling for removing and replacing engine and power train as a single unit
- The time to inspect, measure, and adjust brakes
- The impact of bus weight on fuel, tires, and brakes
- The capability of the manufacturers to run tests on the air conditioners at 115 degrees Farenheit and 5% relative humidity to simulate environmental conditions of one of the participating operators

The prebid conferences were invaluable. Resolving problems associated with the points enumerated above *before bids are submitted* precludes administrative and legal problems.

Chart 4

Manufacturer A's Response to Operator 1 Cost Drivers

O&M Cost Drivers	Maintenance Events	Operator's Maintenance Time	Manufacturer's Maint. Time
Maintenance Factors			
Exterior Skirt Panel	Remove and replace	540 minutes	21.0 minutes
Transmission Oil Cooler	Remove and replace	62 minutes	103.5 minutes
Air Conditioner			
Alternator	Remove, repair, and replace	160 minutes	0
Fan Drive Motor	Remove, repair, and replace	168 minutes	0
Alternator and Fan Drive	Lubricate	9 minutes	0
Compressor	Remove, replace, and align	300 minutes	171.0 minutes
Brakes	Inspect, measure & adjust 4 wheels	8 minutes	4.0 minutes
Operating Factors	**Operator's Utilization Rate**	**Manufacturer's Utilization Rate**	
Fuel	4.9 miles per gallon	No response	
Tires	70,000 miles average tire life	No response	

Chart 5

Manufacturer B's Response to Operator 1 Cost Drivers

O&M Cost Drivers	Maintenance Events	Operator's Maintenance Time	Manufacturer's Maint. Time
Maintenance Factors			
Exterior Skirt Panel	Remove and replace	540 minutes	32.9 minutes
Transmission Oil Cooler	Remove and replace	62 minutes	53.0 minutes
Air Conditioner			
Condenser Motor	Remove and replace	120 minutes	18.4 minutes
A/C Alternator	Remove and replace	160 minutes	29.3 minutes
A/C Blower Motor	Remove and replace	168 minutes	49.6 minutes
Condenser Motor and Brushes	Remove and replace	168 minutes	9.2 minutes
Freon Compressor	Materials cost saving	$450.00	$300.00
A/C Compressor	Remove and replace	300 minutes	199.6 minutes
Brakes	Inspect, measure & adjust 4 wheels	8 minutes	8.0 minutes

Operating Factors	Operator's Utilization Rate	Manufacturer's Utilization Rate
Fuel	4.9 miles per gallon	No change expected from previous bus design experience
Tires	70,000 miles average tire life	No change expected from previous bus design experience

Chart 6

Manufacturer A's Response to Operator 2 Cost Drivers

O&M Cost Drivers	Maintenance Events	Operator's Maintenance Time	Manufacturer's Maint. Time
Maintenance Factors			
Engine	Remove and replace	960 minutes	667.0 minutes
Transmission Oil Cooler	Remove and replace	65 minutes	103.5 minutes
Preventive Maintenance	3,000-mile inspection	210 minutes	No response
Brakes	Inspect, measure & adjust 4 wheels	8 minutes	4.0 minutes
Operating Factors	**Operator's Utilization Rate**		**Manufacturer's Utilization Rate**
Fuel	4.8 miles per gallon		No response
Tires	120,000 miles average tire life		No response

Chart 7

Manufacturer B's Response to Operator 2 Cost Drivers

O&M Cost Drivers	Maintenance Events	Operator's Maintenance Time	Manufacturer's Maint. Time
Maintenance Factors			
Engine	Remove and replace	960 minutes	1,080 minutes
Transmission Oil Cooler	Remove and replace	65 minutes	53 minutes
Preventive Maintenance	3,000-mile inspection	210 minutes	0*
Brakes	Inspect, measure & adjust 4 wheels	8 minutes	8 minutes

*Manufacturer eliminated all 3,000-mile inspections

O&M Cost Drivers	Operator's Utilization Rate	Manufacturer's Utilization Rate
Operating Factors		
Fuel	4.8 miles per gallon	No change expected from previous design experience
Tires	120,000 miles average tire life	No change expected from previous design experience

Chart 8

Operator 1

LIFE-CYCLE COST EVALUATION OF MANUFACTURER A BUS MAINTENANCE COST IMPACT

Maintenance LCC Factors	Maintenance Events	Design Changes	Mfr. Time Per Maint. Event	Operator Time Per Maint. Event Current Fleet	Time Impact Per Maint. Event	No. of Maint. Events (2 yrs.)	LCC Impact Per Bus	LCC Impact on Life of 37 Buses
Skirt Panel	Remove & replace front side panel	Nonstructural - bolted rather than riveted attachment	21.0 min.	540.0 min.	519.0 min.	36	$247	$9,139
Transmission Oil Cooler	Remove, clean, & replace	Cleanable cooler on ADB not on prior buses	103.5 min.	62.0 min.	(41.5 min.)	5	(3)	(111)
Brake Adjustment	Inspect, measure, adjust 4 wheels	Automatic adjustment on ADB	4.0 min.	8.0 min.	4.0 min.	2,919	154	5,696
Air Conditioning								
A/C Alternator	Remove, repair, replace alternator	Eliminated on ADB	0.0 min.	160.0 min.	160.0 min.	50	213	7,881
A/C Blower Motor	Remove, repair, replace motor	Eliminated on ADB	0.0 min.	168.0 min.	168.0 min.	36	80	2,960
A/C Compressor	Remove, replace, & align	Belt driven on ADB, more accessible	171.0 min.	300.0 min.	129.0 min.	124	211	7,807
A/C Alternator & Fan Drive	Lubricate	Eliminated on ADB	0.0 min.	9.0 min.	9.0 min.	291	35	1,295

Operational LCC Factors	Manufacturer's Utilization Rate	Operator's Utilization Rate	LCC Impact Per Bus	LCC Impact on 37 Buses
Fuel	No response	4.9 mpg	Not determined	Not determined
Tires	No response	70,000-mile life per tire	Not determined	Not determined

Chart 9

Operator 1

LIFE-CYCLE COST EVALUATION OF MANUFACTURER B BUS MAINTENANCE COST IMPACT

Maintenance LCC Factors	Maintenance Events	Design Changes	Mfr. Time Per Maint. Event	Operator Time Per Maint. Event Current Fleet	Time Impact Per Maint. Event	No. of Maint. Events (2 yrs.)	LCC Impact Per Bus	LCC Impact on Life of 37 Buses
Skirt Panel	Remove & replace front side panel	Nonstructural - bolted rather than riveted attachment	32.9 min.	540.0 min.	507.1 min.	36	$241	$8,917
Transmission Oil Cooler	Remove, clean, & replace	Cleanable cooler on ADB not on prior buses	53.0 min.	62.0 min.	(9.0 min.)	5	(0.59)	(22)
Brake Adjustment	Inspect, measure, adjust 4 wheels	No change on ADB	8.0 min.	8.0 min.	0.0 min.	2,919	0	0
Air Conditioning								
Condenser Motor	Remove & replace motor	Improved accessibility	18.4 min.	120.0 min.	101.6 min.	50	67	2,479
A/C Alternator	Remove & replace alternator	Improved accessibility	29.3 min.	120.0 min.	90.7 min.	50	60	2,220
A/C Blower Motor	Remove & replace motor	Improved accessibility	49.6 min.	75.0 min.	25.4 min.	36	12	444
A/C Blower Motor Brushes	Remove & replace brushes	Brushes can be changed	9.2 min.	168.0 min.	158.8 min.	36	75	2,775
Condenser Motor & Brushes	Remove & replace motor & brushes	Improved accessibility	29.8 min.	120.0 min.	90.2 min.	50	60	2,220
Freon Compressor	Operating material cost saving	Simplified, lightweight	$300	$450	$150	124	181	6,697
A/C Compressor	Remove & replace	Dual A/C system	199.6 min.	300.0 min.	100.4 min.	124	164	6,068

Operational LCC Factors	Manufacturer's Utilization Rate	Operator's Utilization Rate	LCC Impact Per Bus	LCC Impact on 37 Buses
Fuel	No change expected from previous bus design	4.9 mpg	0	0
Tires	No change expected from previous bus design	70,000-mile life per tire	0	0

Chart 10

Operator 2

LIFE-CYCLE COST EVALUATION OF MANUFACTURER A BUS MAINTENANCE COST IMPACT

Maintenance LCC Factors	Maintenance Events	Design Changes	Mfr. Time Per Maint. Event	Operator Time Per Maint. Event Current Fleet	Time Impact Per Maint. Event	No. of Maint. Events (6 Mos.)	LCC Impact Per Bus	LCC Impact on Life of 205 Buses
Transmission Oil Cooler	Remove, clean, & replace	Cleanable cooler on ADB not on prior buses	103.5 min.	65.0 min.	(38.5 min.)	1 in 4 yrs.	$ 0	$ 0
Brake Adjustment	Inspect, measure, adjust 4 wheels	Automatic adjustment on ADB	0.0 min.	4.0 min.	4.0 min.	544	153	31,365
Power Plant	Disconnect, drain, remove, & replace	More accessible, easier connections	667.0 min.	960.0 min.	293.0 min.	2	41	8,405
Preventive Maintenance	3,000-mile inspection	No response		210.0 min.	Not determined			

Operational LCC Factors	Manufacturer's Utilization Rate	Operator's Utilization Rate	LCC Impact Per Bus	LCC Impact on 205 Buses
Fuel	No response	4.8 mpg	0	0
Tires	No response	120,000-mile life per tire	0	0

Chart 11

Operator 2

LIFE-CYCLE COST EVALUATION OF MANUFACTURER B BUS MAINTENANCE COST IMPACT

Maintenance LCC Factors	Maintenance Events	Design Changes	Mfr. Time Per Maint. Event	Operator Time Per Maint. Event Current Fleet	Time Impact Per Maint. Event	No. of Maint. Events (6 Mos.)	LCC Impact Per Bus	LCC Impact on Life of 205 Buses
Transmission Oil Cooler	Remove and clean	Removable end caps facilitate cleaning	53.0 min.	65.0 min.	12.0 min.	1 in 4 yrs.	$ 0	$ 0
Brake Adjustment	Inspect, measure, adjust 4 wheels	No change on ADB	8.0 min.	8.0 min.	0.0 min.	544	0	0
Power Plant	Disconnect, drain, remove, & replace	More accessible, easier connections	638.4 min.	960.0 min.	321.6 min.	2	45	1,766*
Preventive Maintenance	3,000-mile inspection	Change 3,000-mile inspection interval to 6,000 miles	0.0 min.	210.0 min.	210.0 min.	272	3,993	818,565

Operational LCC Factors	Manufacturer's Utilization Rate	Operator's Utilization Rate	LCC Impact Per Bus	LCC Impact on 205 Buses
Fuel	No change expected from previous bus design	4.8 mpg	0	0
Tires	No change expected from previous bus design	120,000-mile life per tire	0	0

*Maintenance labor savings of $9,225 must be offset by $7,459 for special tool requirements.

Chart 12

Transit Operator 1

Bid Price Adjustment Worksheet

	Offeror	
	Manufacturer A	Manufacturer B
Bus Bid Price	$3,063,322	$3,648,200
ADB LCC Impact	34,679	31,842
Adjusted Bid Price	$3,028,643	$3,616,358

On the basis of this parallel, nonbinding procurement, Manufacturer A would be awarded the contract, since his adjusted bid price represents the lowest cost of ownership over the life of the 37-bus buy.

Transit Operator 2

Bid Price Adjustment Worksheet

	Offeror	
	Manufacturer A	Manufacturer B
Bus Bid Price	$20,210,835	$18,508,252
ADB LCC Impact	39,770	820,331
Adjusted Bid Price	$20,171,065	$17,687,921

On the basis of this parallel, nonbinding procurement, Manufacturer B would be awarded the contract, since his adjusted bid price represents the lowest cost of ownership over the life of the 205-bus buy.

Chart 13

cost drivers. This, in turn, simplifies the entire procurement process; yet effectiveness is not diminished, since the proper choice of the cost drivers represents approximately 75% of the O&M costs. The advantage lies in dealing with a handful of figures in lieu of an array that could measure in the hundreds. In addition, the cost drivers represent the costs of greatest concern to the operators. They also represent the areas of greatest opportunity for the manufacturers to influence the total cost of ownership. Two cost areas that will be listed as cost drivers, tires and fuel, may receive additional attention and are therefore covered in this section.

In the test application, tire costs were not furnished by the manufacturers. The tires are leased by the transit operators directly from tire manufacturers. The bus manufacturer, however, impacts tire life, and thus tire lease cost, by reason of the tire size and design required by the new bus design (weight and front-end suspension). Because of the contractual lease arrangements between the tire manufacturers and the transit operators, AMS believes that the tire lease cost data for each manufacturer's bus should be more easily available to the operators. For this reason AMS believes the tire data should be obtained by the operator from the tire manufacturer from whom he leases his tires; the operator should include this data in the LCC evaluation just as if it had been furnished by the bus manufacturers. The procedures covered in earlier sections of this report include this point.

Because fuel is such a major operating cost, AMS developed an estimated LCC impact of fuel for the ADBs. This was done to demonstrate the significant cost impact that changes in fuel consumption can have on an operator's O&M costs. AMS cites these LCC estimates to show the competitive opportunities that manufacturers have when they direct their attention to the operator's cost drivers. It is important to note that these data were not used by the transit operators in making their LCC adjustments to the manufacturers' price proposals.

In developing the LCC impact of fuel for the ADBs, AMS used the actual average fuel consumption rates of 987 ADBs operating for more than a year at transit operations in six widely separated states, and the prior fleet average fuel consumption rates for the same transit operations. A fuel cost of 80 cents per gallon was used in developing these costs.

The average miles per gallon for the prior fleets was 4.38. The average miles per gallon for the ADBs was 3.08, a decrease of 1.3 mpg per bus. Applying these fuel-consumption rates to Operator 1, it was found that he would experience a $38,544 increase in fuel cost over the life of each new bus, and a $1,246,151 increase in fuel cost over the life of the 37-bus purchase. Operator 2 would experience a $38,544 increase in fuel cost over the life of each ADB, and a $7,901,520 increase in fuel cost over the life of the 205-bus purchase. These fuel cost increases are considered conservative, since the transit operators participating in this study had prior fleet average fuel consumption of 4.9 and 4.8 mpg instead of the prior fleet average of 4.38 mpg used in developing these estimates.

The detailed evaluation data is shown on the charts in the previous section of this report. Of significance is the detail and completeness of the method for recording the data. This means that the data can be used for other purposes than for completing the "Bid Price Adjustment Worksheet," Chart 13. This body of information becomes useful in planning future strategies and making improvement demands. Using the data as shown on Chart 14, page 29, several things become very clear. The bid price differential of one manufacturer must be overcome to draw even with his competitor. When the O&M costs are included, the differential is approximately 5% of this base. Put another way, the bid price differential can be overcome by a three-cents-per-mile improvement over the life of the bus. Chart 14 also shows the dramatic impact of fuel costs on the operating costs. Assuming that both manufacturers admit to a 3.08-mpg efficiency, the bid price differential can be overcome by an improvement of .42 miles per gallon. It should be understood that overcoming the differential only overcomes the handicaps given to the higher bidder. In short, the high bidder's cost improvement must be better than his competitor's by the value of the differential just to stay even.

AMS feels that the "how-to kit" developed during this study and proven workable during the test is a major step in the use of LCC in the procurement process. In addition, by design, the kit is sufficiently flexible to incorporate changes and refinements very readily.

LCC OBSERVATIONS

The following observations were made during the course of this study:

- The LCC data provided by both operators reflected actual data derived from their O&M records.
- Bus fleets operating in different environments have different cost drivers. Varying cost experience is the reason why the AMS LCC approach requires that each operator's current cost experience be established as a baseline for comparison of the LCC impact of the manufacturers' design changes.
- The cost-impact variance is due not only to the environment, but also to such other factors as mechanics' hourly wages, efficiency of the labor force, adherence to recommended preventive maintenance practice, etc.
- Lack of response by the manufacturers to the operators' cost drivers or the failure to provide adequate support for their LCC estimates of impact implies that the ADBs were not designed with LCC in mind. Had they been so designed, complete response and adequate support would have been readily available.
- One participating operator had a computerized recordkeeping system; the other transit operator maintained his records manually. Nonetheless, both operators were able to retrieve and provide the manufacturers with hard, supportable data representing their current fleet average O&M cost

Example of Potential Use of Evaluation Data

Using Operator 1 Data

Bid Price (per unit)
    Manufacturer A - $82,792
    Manufacturer B - $98,600
Bid Price Differential --$ 15,808

LCC Total O&M Cost, Manufacturer B - $295,800
    (AMS estimate, 3 times bid price)

LCC of Cost Drivers - $215,934
    (Operator 1 reported value of 73% of total)

Base Value for Overcoming Bid Price Differential
    LCC of Cost Drivers $215,934
    Bid Price, Manufacturer B - 98,600
Total Value ---$314,534

Ratio of Bid Price Differential to Base Value ------------------- 5.02%

Specified Bus Life - 500,000 miles
Life Benefit of 1¢-per-Mile decrease in Cost - $5,000

Life Cost Needed to Overcome Bid Price Adjustment -----------3.16¢ per mile

Using AMS Fuel LCC at 80¢ per gallon
    Cost at 4.38 miles per gallon - 18.26¢ per mile
    Cost at 3.08 miles per gallon - 25.97¢ per mile
Fuel Cost Differential ------------------------------------7.71¢ per mile

Assuming Both Manufacturers at 3.08 Miles Per Gallon
    Fuel improvement to overcome bid price adjustment - .42 miles per gallon

Chart 14

experience.

- Most of the manufacturers' estimates of ADB LCC impact were related to improved time to remove and replace an assembly, subassembly, or component due to improved accessibility.

- The operators' LCC evaluations of the manufacturers' estimates of cost impact showed that some had a negative impact (increased cost), some had a positive impact (decreased cost), and others had no impact at all on the operators' current fleet cost experience.

- On the basis of their LCC evaluations, the operators invalidated certain estimates of impact by the manufacturers, as in the case of transmission oil cooler.

- The prebid conferences or technical clarification meetings proved invaluable to both the manufacturers and the operators in resolving technical questions on the part of both parties. These questions, if unresolved, could have resulted in legal problems in a live procurement.

CONCLUSIONS

On the basis of this study, AMS concludes the following:

- A major step has been taken to make life-cycle costing a viable alternative to the current low-bid acquisition method for the purchase of urban-type buses.

- The necessary operating and maintenance data are available at the operator's level.

- The operators demonstrated the capability of retrieving the necessary O&M data and using it effectively to measure the impact of the ADB design changes on their current fleet cost experience.

- The manufacturers demonstrated the capability of identifying their ADB design features which had an impact, negative or positive, on the operators' current fleet cost experience; they were also able to estimate and support the level of impact such design features would have.

- The AMS procedures and guidelines are adequate to provide the necessary direction and control for transit operators and bus manufacturers to apply LCC in the procurement of urban buses.

- Comparison of operators' O&M costs is not meaningful unless differences in environments, hourly wage rates, efficiency of maintenance programs, are understood.

- Adherence to the recommended procedures will do much to reduce the time for completion of the procurement cycle.

- A program directed at improving the ADB design features which affect the operators' cost drivers would pay big dividends in reduced follow-on O&M costs.

- An operator's O&M data need not be computerized to be used effectively in the LCC procurement of urban buses.

- When LCC analysis is made a mandatory part of the procurement process, marked improvement in participation by both the buyer and the seller should be experienced, with considerably more engineering involvement.

- Modification of the operators' cost reporting systems to better track their O&M costs will improve their management capability significantly and optimize the use of LCC.

- The total impact of LCC in this study would have been altered appreciably if the manufacturers had responded to all of the operators' cost drivers.

- The LCC tire data is more available to the transit operators directly from the tire manufacturer than from the bus manufacturer because of the leasing arrangement between the operator and the tire manufacturer.

RECOMMENDATIONS

On the basis of the observations and conclusions of this study, AMS recommends that:

- The LCC procedures and guidelines included in Appendix E of this report be adopted by UMTA for use by the transit operators in implementing future LCC purchases of urban buses.

- Appendices B, C, and D to this report be used as a baseline in effecting controls and changes.

- The bus manufacturers respond to all of the operators' cost drivers, except the tire cost driver, or their bids will be considered nonresponsive and returned.

- The manufacturer's estimates of his ADB cost impact on any of the operator's cost drivers be declared invalid if the manufacturer fails to provide adequate supporting data for that estimate.

- The transit operator obtain the LCC tire data for each manufacturer's ADB directly from the tire manufacturer and use this data in his LCC evaluation.

- Transit operators develop an ongoing knowledge of their O&M costs which can be used to enhance their management capabilities and which will enable them to use LCC most effectively as a procurement tool.

- The manufacturers and their vendors conduct the tests necessary to permit them to predict accurately the impact of design changes on operators' costs such as fuel consumption, tire and brake wear, etc.

- Future design changes to the ADB be made with LCC in mind in order to take full advantage of the benefits availablé to the manufacturer when LCC is used.

- UMTA and the manufacturers jointly support an R&D program directed at improving those ADB features responsible for the higher O&M cost drivers.

- The manufacturers, working closely with the transit operators and using their vast experience in maintaining buses, develop more cost-effective preventive maintenance procedures to be followed by the operators.

- The operators modify their cost reporting systems, as necessary, to relate cost accounts to the specification and to track their costs more easily.

Appendix A

CANDIDATES CONTACTED FOR LIFE-CYCLE COSTING FEASIBILITY STUDY

*Phoenix Public Transit System, Phoenix, Ariz.

*Brockton Transit Authority, Brockton, Mass.

*Pioneer Valley Transit Authority, Springfield, Mass.

*Massachusetts Bay Transportation Authority, Boston, Mass.

Niagara Frontier Transit Metro System, Buffalo, N. Y.

Rapid Transit Lines, Inc., Houston, Tex.

Dept. of Public Works, Milwaukee County, Milwaukee, Wisc.

Southeastern Pennsylvania Transportation Authority, Philadelphia, Penna.

Augusta Transit Dept., Augusta, Ga.

Metropolitan Transit Authority, Nashville, Tenn.

*Metropolitan Suburban Bus Authority, Carle Place, N. Y.

*Greater Cleveland Regional Transit Authority, Cleveland, Ohio

Toledo Area Regional Transit Authority, Toledo, Ohio

Southwest Ohio Regional Transit Authority, Cincinnati, Ohio

Charlotte City Coach Lines, Inc., Charlotte, N. C.

City of Detroit Dept. of Transportation, Detroit, Mich.

*Regional Transportation Authority, Chicago, Ill.

*Properties visited

Appendix B

COST ELEMENTS

A	B	C	D*
Structural Components and Finish			
	Shell		
		Finish	
		Numbers and signs	
		Windows	
		Doors	
		Advertising panels	
		Other	
	Exterior		
		Panels	
		Rubrails	
		Access doors	
		Wheel housing	
		Skirts and aprons	
		Other	
	Interior		
		Driver barrier	
		Panels and bulkheads	
		Access doors	
		Seats	
		Stanchions & handrails	
	Floor		
		Covering in vestibule	
		Stairwells & passenger compartments	
		Other	
Operating Equipment			
	Door actuators		
	Windshield wipers		
	Windshield washers		

*Detailed and total costs would be shown in Column D. Use of these cost elements explained on pages 4 and 5.

A	B	C	D*
Operating Equipment (continued)			
	Lighting & signals		
	Driver controls		
	Driver instruments		
	Mirror		
	Destination signs		
	Loading system		
	Farebox		
	Other		
Chassis			
	Power plant		
		Engine	
		Cooling system	
		Fuel system	
		Oil lines	
		Transmission	
		Engine accessories	
		Hydraulic drive	
		Rear-axle assembly	
		Drive shaft	
		Other	
	Brakes		
		Hubs and drums	
		Air system	
		Other	
	Suspension & steering		
		Front axle	
		Steering	
		Spring & shock absorbers	
		Other	

*Detailed and total costs would be shown in Column D.

A	B	C	D*
	General		
		Frame	
		Wheels	
		Bumpers	
		Other	
Other Major Systems			
	Electrical system		
		Generator/alternator	
		Voltage regulator	
		Starting motor & drive	
		Batteries	
		Other	
	Climate control		
		Heating	
		Air conditioning	
		Ventilating	
		Other	
	Air operation system		
	Communications equipment		
	Other		
Fuel			
Tires			
Oil			
Preventive Maintenance			
	Oil change		
	Lubrication		
	Inspection		
	Tuneup		

*Detailed and total costs would be shown in Column D.

A	B	C	D*
Preventive maintenance (continued)			
	Washing		
	Cleaning		
	Other		
	TOTAL- - - - - - - - - -	- - - - - - - - - - - - - - - - - - - -	

*Detailed and total costs would be shown in Column D.

Appendix C

DESIGN CHANGES WHICH AFFECT

LIFE-CYCLE O&M COSTS

In the charts on the following pages, the column headed "Specification Reference" shows the paragraph number of the UMTA "Baseline Advanced-Design Transit Coach Specification." The column headed "Subject" shows the title or abbreviated subject title of that paragraph.

The column entitled "Change to Effect Potential Saving" lists suggestions of ways in which costs can be reduced. The more obvious changes are listed in this column, but savings can also be effected by: (1) extending the time interval between maintenance actions (2) reducing the times for accomplishing the repair action, (3) reducing the number of mechanics and/or their skill levels to accomplish the repair action, and (4) reducing the cost of the replacement parts.

In addition, the last two items in this listing, "Preventive Maintenance" and "Fuel Requirements," do not have specific paragraph references but do have a relationship with segments of the specification and are properly listed with other areas of potential savings.

Specification Reference	Subject	Change to Effect Potential Saving
1.5.2.1	Interchangeability	Standard set at 26,000 lbs. Lighter bus could provide savings.
1.5.4.2	Maintenance and Inspection	Extend time between routine scheduled maintenance such as filter replacements & adjustments.
1.5.4.3	Mean Mileage Between Failures	Extend mileage for road calls, coach change, and bad order.
1.5.4.4	Mean Time to Repair	Reduce repair times and/or reduce skill levels for repair compared to buses manufactured before 1977.
1.5.4.5	Accessibility	Reduce periodic maintenance time requirement by improving accessibility for service and inspection.
1.5.4.6	Interchangeability	Provide higher degree of interchangeability commensurate with inventory items.
2.1.1.3	Finish and Color	Increase life of exterior finish.
2.1.1.4	Numbering and Signing	Extend life of monograms, numbers, and other special signing.
2.1.1.6	Passenger Windows	Trade off window surface for cooling & heating requirements (12,000 may not be appropriate for all locations.)
2.1.3.2	Repair and	Reduce time to replace side panels above and below rubrail, and/or require lower skill level to do job in same time.
2.1.3.5	Rubrails	Reduce time to replace damaged rubrails.
2.1.6.2	Stepwell Structure	Reduce replacement time and increase durability.
2.1.7.3	Fender Skirts	Increase durability and reduce replacement time.

Specification Reference	Subject	Change to Effect Potential Saving
2.1.8.1	Materials (Passenger Door)	Extend life of door opening mechanism (reliability).
2.1.9.1	Interior (Access Doors)	Eliminate or reduce need to remove fixtures and equipment unrelated to the task to gain access to doors.
2.2.1.3	Actuators (Door)	Extend life of door actuators and allow for easier adjustments.
2.2.2.1	Windshield Wipers	Extend life of windshield wipers, motors, and mechanisms, and allow for easier serive and reduced time for replacement.
2.2.2.2	Windshield Washers	Reduce service and repair time.
2.2.3.1	Exterior Lighting	Provide longer lasting lights, ease of access, and greater degree of interchangeahility.
2.2.3.2	Service Area Lighting	Provide longer lasting lights and allow for greater interchangeability.
2.2.3.3	Passenger Interior Lighting	Provide longer lasting lights; allow for easier accessibility and greater degree of ingerchangeability
2.2.3.5	Driver Controls	Provide longer lived switches and allow for easier replacement and servicing.
2.2.3.5	Instrumentation	Provide for reduced servicing and replacement of instruments and wiring; allow for easier access.
2.3.1.1	Trim Panels	Reduce replacement time and increase degree of interchangeability.
2.3.1.3	Front Panels	Reduce replacement time.
2.3.1.4	Rear End	Reduce replacement time.

Specification Reference	Subject	Change to Effect Potential Saving
2.3.2.4	Construction and Material (Passenger Seats)	Improve durability, reduce replacement time, and increase degree of interchangeability.
2.3.4	Floor Covering: Vestibule, Driver Compartment, Pasenger Area	Improve durability, reduce replacement time.
2.4.1	Driver Windows, Windshield, & Side Window, ¼" Laminated Safety Glass	Increase durability, reduce replacement time.
2.4.2	Side Windows	Improve durability, reduce replacement time.
2.6.4.1	Destination Signs	Reduce servicing time, increase durability of mechanism, & reduce replacement time.
2.6.6.2	Loading System	Increase life between failure; reduce replacement, repair, and adjustment time.
3.1.1.6	Operating Range	Extend range with same fuel capacity, or maintain 350 miles with less fuel capacity.
3.1.2.2	Service (Power Plant)	a. Reduce removal, replacement, and service time on power plant and accessories and/or reduce personnel in skill & numbers. b. Extend time between oil changes and filter replacement.
3.1.2.4	Hydraulic Drive	Extend mean time to repair (excess of 50,000 miles); reduce service and replacement time.
3.1.3.2	Cooling System	Provide easier accessibility and reduce replacement time for thermostats, filters, coolant, radiators, coolant tanks, and hoses.
3.1.3.3	Transmission	Reduce time for removing, replacing, and preparing for service.

Specification Reference	Subject	Change to Effect Potential Saving
3.3.1	General Requirements (Suspension)	Reduce time to service & replace bushings and air springs.
3.3.2.2	Kneeling	Reduce time for servicing and preventive maintenance.
3.3.2.3	Damping	Extend life of shock absorbers and reduce replacement time.
3.3.2.4	Lubrication	Reduce lubrication time for the coach and extend time between lubrications.
3.5.1.2	Friction Material (Service Brakes)	Extend life of friction material; reduce overhaul or replacement time.
3.5.1.3	Hubs and Drums	Extend life of wheel bearings and huh seals and reduce replacement time.
3.5.1.4	Air System	Reduce service time, including replacement of hoses & dessicant beds.
3.6.2.1	Fuel Tank	Reduce inspection, cleaning, and replacement times.
3.6.3.2	Front Bumper.	Increase impact speeds for bus damage; reduce replacement time; provide warranties for energy-absorption system for life of coach.
3.6.3.3	Rear Bumper	Same.
3.6.4.2	Modular Design (Electrical System)	Provide greater reliability; reduce removal and replacement times.
3.6.4.4	Junction Boxes	Extend life and reduce service and replacement times.
3.6.5.1	Electrical Com-	Extend life and reduce service and replacement times of components such as switches, relays, flashers, circuit breakers, and electric motors.

Specification Reference	Subject	Change to Effect Potential Saving
3.6.5.2	Batteries	Extend life and reduce service and replacement times.
3.7.1	Capacity and Performance (Interior Climate Control)	Reduce service requirements and time to service and/or replace components.
3.7.4	Air Intakes	Reduce time for servicing and replacing air filters.
---	Preventive Maintenance	Develop PM procedure & sequencing to reduce PM time requirements for partial or complete PM operations.
---	Fuel Requirements	Reduce fuel requirements per mile, weight, power plant, route travel profile, etc.

Appendix D

TESTS, DEMONSTRATIONS, STANDARDS FOR LIFE-CYCLE COST SUPPORT

Part 1 - Tests (Examples)

Specification Reference	Test to Be Performed
2.1.2.5	Corrosion Test
2.1.2.6	Towing Test
2.1.2.7	Jacking
2.1.2.9	Fire Protection
2.1.2.10	Crashworthiness (top, sides)
2.1.3.5	Rubrails
2.1.4.3	Modesty Panels
2.1.5.2	Strength (floor)
2.1.5.4	Floor Protection
2.1.6.2	Stepwell Structure
2.1.7.2	Clearance (tire chain, and tires and coach)
2.1.7.3	Fender Skirts
2.1.7.4	Splash Aprons
2.2.1.2	Closing Force (doors)
2.2.1.3	Actuators (door, life of)
2.2.3.3	Passenger Interior Lighting (illumination, fire resistant)
2.2.3.4	Driver Lighting (illumination)
2.3.2.3	Structure and Design (seats), Loads on Passenger Seats, Handholds, and Armrests

Specification Reference	Test to Be Performed
2.5.1	Properties (insulation), Fire Resistant
2.5.2.2	Sound Insulation (standstill and moving)
2.6.1.2	Vision (light transmission)
2.6.3.1	General Requirements (passenger assists), Forces
3.1.4.3	Exterior Noise (generated by coach)
3.3.2.1	Travel (springs and shock absorbers), Change in Height Due to Loading
3.4.1	Strength (steering components)
3.4.3	Turning Effort
3.5.1.1	Actuation (service brake)
3.5.1.4	Air System (sizing and functioning)
3.6.3.2	Front Bumper (impact test)
3.6.3.3	Rear Bumper (impact test)
3.7.1	Capacity and Performance (interior climate control system)
3.7.3.1	Passenger Area (air flow)
3.7.4	Air Intakes (result of filtered air)

Part 2 - Maintenance Tasks, Times, and Required Skill Levels

Specification Reference	Task and Performance Time	Mechanic Skill Level Required*
1.5.4.2	Scheduled maintenance or implementation tasks	3M
2.1.2.7	Jacking - jacking complete in 2 minutes	2M
2.1.3.2	Panel replacement - lower, 5 feet long, 30 minutes; upper, 5 ft. long, 1½ hours	3M 3M
2.2.3.1	Exterior light replacement, 5 minutes	2M
3.1.2.2	Service (power plant) - remove, replace, prepare engine and transmission for service - less than 20 hours	two 3M
3.1.3.3	Transmission - remove, replace, and prepare transmission for service - 8 combined hours	3M plus optional help
3.3.2.3	Damping - replace each shock absorber - 15 minutes	2M
3.6.4.2	Modular design (electrical system) - remove and replace modules (except main body wiring power) - 30 minutes	3M
3.6.4.4	Junction boxes (if located on side wall, replaceable as unit) - 15 minutes	3M
3.6.5.1	Electrical components (switches, relays, flashers, and bircuit breaker) - 5 minutes; (electric motor bunker) - 15 minutes	3M

*These skill levels correspond to those defined in the specification, with the understanding that a lower skill level is acceptable for specification compliance.

Part 3 - Cross-Referenced Standards and Practices

Specification Reference	Standard Practice	Area Covered
1.2(10)	SAE Recommended Practice J941	Driver's eye range
1.2(12)	ASTM-E 162-75	Fire resistant
1.2(13)	SAE Recommended Practice J833	Human dimensions
2.1.2.5	ASTM Procedure B-117	Corrosion
2.1.7.2	SAE Information Report J683	Tire chain clearance
2.2.3.1	SAE Standard J593	Visible reverse operation warning
2.2.3.1	SAE Recommended Practice J994, Type C or D	Audible reverse operation warning
2.2.3.5	SAE Recommended Practice J287	Driver hand control reach
2.2.3.6	SAE Recommended Practice J678	Speedometer sizing and accuracy
2.4.1.1	SAE Recommended Practice 1050	Driver's field of view
2.4.2.2	ANSI Z26.1-1966	Glazing material (side windows)
3.1.4.3	SAE Standard J366	Instrumentation and test sites for exterior noise
3.3.2.4	SAE Standard J534	Grease fittings
3.5.1.4	SAE Standard J844	Tubing for air lines
	SAE Standard J10	Air reservoirs
3.6.4.3	SAE Recommended Practice J555) SAE Recommended Practice J878,) Type SLX)	Electrical wiring except
	SAE Standard J558, Type SGT) SAE Recommended Practice J541)	Battery and starter wiring
3.6.5.2	SAE Standard J537, Type 20T8	Lead acid batteries

Appendix E

LIFE-CYCLE COST PROCUREMENT PROCEDURES AND GUIDELINES

These LCC procurement procedures and guidelines represent the ground rules to be followed by the purchaser (operator) and the seller (bus manufacturer) in making life-cycle cost procurements, in lieu of the conventional low-bid acquisition type of procurement. The guidelines supplement the LCC procurement procedures by providing greater detail. Both have been developed and tailored for application in the procurement of urban buses.

Life-Cycle Cost Procurement Procedures

Methodology

The following are step-by-step procedures to be followed by the transit operator and the bus manufacturers in a procurement of buses. They provide for the issuance of an invitation for bids (IFB) containing a requirement to submit a technical and price proposal in a single bid package. This bid package will consist of the following:

I. Technical Proposal

a. The request by the purchaser (operator) for a technical proposal will:

1. Identify the operator's current highest operating and maintenance (O&M) cost factors (cost drivers). The following terms are suggested:

(a) Fuel in miles per gallon.

(b) Tire life in miles

(c) Oil, lubricating, in miles per quart.

(d) For other cost drivers such as brakes, air conditioning, transmissions, etc., identify:

(1) Removal and replacement time and number of occurrences over the measured period.

(2) Repair time and frequency of repair over the measured period.

(3) Inspection and cleaning time and frequency over the measured period.

(e) Preventive maintenance intervals (3,000, 6,000, 10,000 miles) and maintenance hours and material cost.

These cost factors should be derived from the operator's actual fleet average O&M costs over two years, or as close to that period as possible. This is the "measured period" referred to above. These costs must include both labor and material costs. The factors selected should be the highest cost factors, representing 70% to 75% of the operator's total O&M costs.

2. Require each bus manufacturer to provide the operator with a substantiated estimate of its ADB's LCC impact, positive or negative, on the operator's cost drivers, except for tire data, which the operator will obtain directly from the tire manufacturer.

b. The bus manufacturers will respond to the operator's IFB by:

1. Addressing each of the operator's high-cost O&M factors, excluding tires, and estimating the impact the corresponding features on their ADBs will have on these cost drivers.

2. Providing substantiation and support for their LCC estimates in the terms set forth in para. IA2 above.

II. Price Proposal

The price proposal will consist of the manufacturer's price for a delivered bus, including warranties.

<u>Sequence of Events</u>

I. Issuance of the IFB

II. Prebid Conference

a. There will be a need for a prebid conference to resolve technical questions prior to submission of technical and price proposals. This meeting will be held by the operator, with all potential bidders present.

b. The meeting will be schedule by the operator and listed in the IFB.

c. The purpose of the prebid conference will be to:

1. Assure that the bidders understand the cost drivers identified in the IFB.

2. Assure the operator that he has a complete understanding of material that will be submitted by the bidders for those specific cost drivers. The operator should limit his comments

to expressions of understanding and should avoid remarks that could be construed as approval or disapproval.

3. Make every effort to assure that the proposals will be adequate, complete, and useful for evaluation by the operator.

4. Provide a record of all discussions, which will be made available to all bidders.

III. Submission of Bids

The bid will be submitted as a package consisting of a technical proposal and a price proposal, as described above.

IV. Evaluation and Price Proposal Adjustment

The operator will evaluate the bidders' technical proposals, including LCC tire data, in terms of acceptable, well-supported operating and maintenance costs over the buses' life of 500,000 miles each. (See Figure 3, pages E-15 and E-16, for detailed calculations.) The operator will then adjust each bidder's price proposal by the amount of the LCC impact on the O&M cost factors considered, multiplied by the number of buses being purchased. This adjusted figure represents the "cost of ownership," the sum total of the initial cost of the buses and the O&M costs for the selected cost factors over the life of the buses purchased.

V. Contract Award

Following the technical proposal evaluation and the price proposal adjustment, the operator makes the contract award to the bidder whose adjusted price proposal reflects the lowest cost of ownership.

Life-Cycle Cost Procurement Guidelines

General

The derivation and the application of the data for applying LCC in the procurement of the Advanced-Design Bus (ADB) are prescribed herein. Ground rules and guidelines applying to both the bus manufacturer and the transit operator are identified separately. Changes will be made to these guidelines, as necessary, by means of addenda.

Current cost experience is limited to on-the-street buses. Ownership of the ADB is expected to result in a different cost picture because of design and manufacturing changes. These changes may increase, decrease, or have no effect upon current cost experience; however, the transit operator must be in a position to identify those O&M cost factors which represent his highest cost drivers and be able to measure, evaluate, and accept or reject estimates made by the manufacturers of the cost impact their ADBs will have on the operator's cost drivers. Therefore the entire LCC process will be improved when the bus manufacturers provide the operator with detailed supporting data for any estimates of cost impact.

The cost factors considered in an LCC procurement are limited to those factors which can be affected by the manufacturers through technological change. A list of such factors is shown in Figure 1, page E-5. Excluded from LCC consideration are such very real O&M costs as drivers' wages, maintenance of shop equipment, G&A, insurance, etc. Warranted items are included in LCC consideration because LCC is interested only in the O&M cost of the item and not in who pays that cost, the manufacturer or the operator.

The cost factors to be considered in LCC procurement of ADBs, as shown in Figure 1, are known to both the manufacturer and the operator. It is from these cost factors that the operator develops his O&M cost drivers for submission to the manufacturers.

The manufacturers' estimates of ADB impact and the operator's evaluation of these estimates will apply to these cost factors. In the evaluation process attention is focused upon cost impact over the life of the bus, which has been established at 500,000 miles. All LCC cost should be based upon current dollars over the life of the equipment.

<u>Bus Manufacturer Guidelines</u>

The bus manufacturers should give close attention to the list of cost drivers shown in para. Ia of the "Methodology" portion of the procedures. These are derived from the complete array of costs as shown in Figure 1, page E-5. This is the only basis against which the manufacturer can expect the transit operator to accept any manufacturer's estimate of cost impact on his current fleet cost experience.

The transit operator has a need to know the bus selling price (acquisition cost) and all that is included in that price (specific warranties, etc.). In addition, there is a need to know the anticipated bus operating and maintenance costs, the derivation of these costs, and the results of any tests to support these costs as they relate to the operator's cost drivers.

The manufacturer's estimates of ADB impact, submitted to the operator in response to his request for LCC data, should be made in terms of measurable costs of operation and maintenance, such as:

- Component or assembly replacement cost (material)
- Time to remove and replace
- Repair time
- Number of mechanics and skill level to do a job

LCC Cost Factors

- BODY
  - Shell
    - Ext. & Applied Panels
    - Finish
    - Skirt Aprons
    - Floors
    - Steps & Stepwells
    - Wheel Housing
    - Passenger Doors
    - Service Compart. Serv. Doors
  - Operating Components
    - Door Actuators
    - Windshield Wiper/Washer
    - Light Control & Instruments
    - Fare Box
    - Loading System
    - Signals
  - Interior
    - Mirror
    - Passenger Seats
    - Driver Seats
    - Floor Covering
    - Panels & Bulkheads
    - Access Doors
    - Stanchions & Handrails
  - Windows
    - Driver's Windows
    - Side Windows
- CHASSIS
  - Propulsion System
    - Engine
    - Cooling System
    - Transmission
    - Engine Accessories
    - Hydraulic Drive
  - Final Drive
    - Rear Axle
    - Drive Shaft
  - Suspension
    - Springs & Shocks
    - Front Axle
    - Kneeling
  - Steering
  - Brakes
    - Hubs & Drums
    - Air System
    - Friction Material
  - General Chassis
    - Wheels
    - Fuel System
    - Bumper System
    - Frame
    - Electrical System
    - Electrical Components
  - Climate Control
    - Heating
    - Air Conditioning
    - Ventilation
  - Radio & Public Address System
    - Mobile Radio System
    - Public Address System
- ROAD CALLS
- PREVENTIVE MAINTENANCE
  - Oil Change
  - Tuneup
  - Inspections
  - Lubrications
  - Cleaning & Washing
- OPERATING FACTORS
  - Fuel
  - Tires
  - Oil

Note: This breakdown is one that the properties currently visualize as related to their cost experience. It varies to some extent from the ADB-specification-oriented breakdown shown in Appendix B, which is preferred and recommended by AMS.

Figure 1

- Anticipated component life or number of changes to be expected during bus life

- Preventive maintenance required

- Standardization equating to reduced inventory costs

- Inspection and cleaning time

- Fuel, oil, and tire costs in miles per gallon, miles per quart, and miles per replacement respectively

The cost drivers will be broken down to the actual subassemblies and components that go to make up the work package under such items as brakes, air conditioning, transmissions, etc., as shown in the first column of Figure 2, "Life-Cycle Cost Worksheet for ADB Design Impact on Operator's Current Fleet Experience" (pages E-10 through E-13). It is to this detailed breakdown that the manufacturer must provide estimates of cost impact.

Because of the contractual lease arrangement between the operators and the tire manufacturers, the bus manufacturers need not furnish a tire cost. Tire cost impact will be an LCC consideration made on the basis of data obtained directly from the tire manufacturers by the operator.

Each estimate must be supported by test data, time study data, engineering analysis, or experience data. The types of tests used to demonstrate compliance with the requirements of the ADB technical specification can also be used to support estimates of impact. For example, the test that demonstrates a life of 5,000 cycles should be used to show that the life has been extended to, say, 10,000 cycles. Similarly, a demonstration that shows that a bus feature meets the specification-required repair time of 30 minutes would also be used to show that an improved design reduced the repair time to, say, 15 minutes.

Since certain types of tests are necessary to demonstrate design acceptance, a dual analysis for life-cycle costing is implied. First, the design change would be demonstrated as being workable and acceptable; then the follow-on cost impact of that change would be analyzed. The following types of tests would be appropriate to support LCC estimates of ADB impact by manufacturers:

- Life-cycle demonstrations to identify the life of a mechanism

- Functional tests to demonstrate that components have a longer life or perform multiple functions

- Visual tests to confirm design improvements such as driver's eye range, reverse-operating warning devices, etc.

- Time demonstrations to show increases or decreases in times of skill levels to perform certain maintenance tasks. Where bus manufacturers time study operations, the observed times shall be submitted to the property for LCC evaluation -- that is, without leveling; with no allowance for fatigue, unavoidable delays, or personal time; and excluding setup time.

- Physical measurement to insure minimum or maximum dimensions are met.

- Gauged (metered) measurements requiring two tests for verification, as for climate control, noise, etc.

- Impact tests requiring duplication for verification, as in tests of bumpers, coach top, etc.

- Street tests to demonstrate acceptability of certain bus features in a real-life environment

- Supplier (vendor) tests to verify the acceptability of various material properties such as fire resistance, corrosion resistance, and material strengths

- Tests of preventive maintenance procedures to be applied by the transit operator, the skill level of the mechanic, together with time standards against each required action, or complete preventive maintenance list. Different preventive maintenance procedures may be applied at various intervals.

Fuel consumption is a major operating expense and will appear as a significant cost driver on every transit operator's list. For this reason it is necessary that the bus manufacturers furnish the transit operator with fuel consumption data that has been developed during the duty-cycle test runs described in Section 1.2(17), Definition, "Design Operating Profile," ADB Specification.

The transit operator's ability to evaluate effectively and objectively the impact of all manufacturers' design changes upon its O&M cost drivers depends upon the completeness and clarity of the description of the changes furnished. Part numbers, photographs, illustrations, maintenance cuts, and schematics should be used as necessary for this purpose.

Bus manufacturers can expect the transit operator to request additional data at the prebid conference to permit more accurate and objective evaluation of estimates of cost impact. Manufacturers' estimates of LCC impact which are not substantiated, which are unverified, or which cannot be related to the experience of the operator lose their credibility. It is therefore important that the manufacturer make every effort to provide the operator with acceptable support for each estimate of ADB impact. A manufacturer who fails to provide adequate support for any estimate of impact on the operator's cost driver cannot expect credit for that cost impact.

Transit Operator Guidelines

The transit operator shall develop a reliable portrayal of his highest cost drivers. These cost drivers should represent 70% to 75% of his total O&M costs over a period of two years, or as close to that period as possible.

These costs should include both labor and material and should be derived from the operator's actual fleet average O&M costs for that period of time.

Costs associated with drivers' wages, garage and garage equipment maintenance, taxes, advertising, safety, administration, etc. will be excluded from LCC consideration. Costs associated with repair of warranted items will be included in LCC consideration, even though these costs have been assumed by the manufacturer.

The bus manufacturer impacts tire life but, because of the contractual leasing arrangement between the operator and the tire manufacturer, the transit operator should obtain the LCC tire data directly from the tire manufacturer. The operator will evaluate this data for award purpose as if it were obtained from the bus manufacturer.

The cost drivers developed by the operator shall be limited to those that can be affected by the manufacturers through technological changes, selected from the list of cost factors shown in Figure 1, page E-5. Each cost driver will be broken down to a level that will reflect the work packages as organized by subassemblies of major assemblies, as follows:

Air Conditioning

Condenser Motor --------------- Remove and replace
Condenser Motor --------------- Rebuild
Condenser Motor and Brushes --- Remove and replace
Compressor -------------------- Remove and replace
Compressor -------------------- Rebuild
Alternator -------------------- Remove and replace
Alternator -------------------- Rebuild
Blower Motor ------------------ Remove and replace
Blower Motor ------------------ Rebuild
Blower Motor Brushes ---------- Remove and replace

This breakdown is important because it shows that some brushes can be removed from the motor without having to remove the motor itself. In other cases the motor must be removed just to replace the brushes. Where the maintenance of brakes is involved, particular care should be exercised in detailing the extent of each maintenance event and giving the operator's time for each event and its fleet frequency for a specified time period. For example:

Cost Factor	Maintenance Event	Fleet Frequency (2 Years)	Operator Time Per Maint. Event
Brakes	Inspect, measure, adjust	2,800	10 min.
	Remove 2 front wheels, inspect race & bearings, turn drums as required, replace blocks & seals, & replace wheels	125	360 min.

Cost Factor	Maintenance Event	Fleet Frequency (2 Years)	Operator Time Per Maint. Event
Brakes (continued)	Remove 2 rear wheels; inspect race & bearings; turn drums as necessary; replace blocks, seals, & wheels	250	480 min. (1 man)

This breakdown is important because the variations in both frequency and time per maintenance event are significant between front and rear brakes.

The key to the success of LCC evaluation is the determination of the value of the design change to the user. For this reason the transit operator will evaluate each claim made by all manufacturers in relation to its current O&M cost drivers. "On the street" experience is not always available to the manufacturer for calculating predicted cost impact on the operator's cost drivers, and a manufacturer's estimates cannot always be aligned with the operator's maintenance procedures, skill mix, or operating environment. It is therefore essential that the transit operator know the manner in which estimates are supported (i.e., by test results, analytical studies, demonstrations, or by on-the-street trials of preproduction buses).

It is imperative that the manufacturers' estimates of impact be verifiahle to determine the value to be given to each estimate by the operator. Manufacturers' estimates of impact which are unsubstantiated and/or cannot be verified, or which cannot be related to the experience of the operator, should be challenged and rejected.

Life-cycle costing encourages the manufacturers to make design tradeoffs between initial costs and follow-on costs. For example:

- Positive estimates of impact from longer life of new, more complex systems such as transmissions may be realized, but consider what the added complexity will mean in terms of added labor and parts costs over the bus life.

- The increase in the bus weight may improve structural and corrosive-resistance characteristics but may impact fuel consumption and tire and brake wear adversely.

- Component quality improvements may extend the life of the part and reduce the cost of maintenance, but these cost benefits may be offset by the initial and replacement material costs.

The transit operator should therefore evaluate the manufacturers' tradeoffs using its current operating experience as a base of comparison.

Since each step of the evaluation is subject to questioning by the bidders or may be protested in a court of law, it is very important that every step be documented. For this reason it is recommended that the operator use a worksheet similar to the one set forth in Figure 2, pages E-10 through E-13, for documentation purposes.

Life-Cycle Cost Worksheet for ADB Design

Maintenance/Operating Factors	Manufacturer's Life Cycle Data			
	Maintenance/ Operation Events	Design Changes	Mfr's Time Per Maint. Event ADB	ADB Unit Mat'l Cost Per Event
BODY				
Windows				
Driver's Windows				
Side Windows	Remove & replace sash	Unbreakable plastic sash - no replacement	0	0
CHASSIS				
Propulsion System				
Engine	Disconnect, drain, remove & replace	More accessible, easier disconnects	667 min.	No impact
Cooling System				
Transmission				
Engine Accessories				
Hydraulic Drive				
Final Drive				
Rear Axle				
Drive Shaft				
Suspension				
Springs and Shocks				
Front Axle				
Kneeling				
Steering				
Brakes				
Hubs and Drums				
Air System				
Friction Material				

Figu

Impact on Operator's Current Fleet Experience

Operator's LCC Data and Evaluation Results						
Current Fleet Unit Mat'l Cost Per Event	Oper. Time Per Maint. Event Current Fleet	Time Impact Per Maint. Event	No. of Maint. Events (2 Yrs.)	Material Impact Per Maint.	$ Impact Per Bus Life	$ Impact on Life of (No.) Bus Buy
$85.00	45.5 minutes	45.5 min.	39	$85.00	$357.00	$13,209 (37 buses)
No impact		960.0 min.	2	0	41.00	8,405 (205 buses)

re 2

Maintenance/Operating Factors	Manufacturer's Life Cycle Data			
	Maintenance/ Operation Events	Design Changes	Mfr's Time Per Maint. Event ADB	ADB Unit Mat'l Cost Per Event
Electrical System				
Batteries				
Relays				
Voltage Regulator				
Climate Control				
Heating				
Air Conditioning				
A/C Fan Motor	Remove and replace	Eliminated on ADB	0	0
A/C Compressor	Remove, re- place, align	Belt driven on ADB, more accessible	171 min.	0
Ventilation				
Preventive Maintenance				
Oil Change				
Tuneup				
Inspections	3,000 mile inspection	Change insp. interval from 3,000 to 6,000 miles	0	0
Lubrication				
Cleaning and Washing				

OPERATING FACTORS	Manufacturer's Utilization Rate	Operator's Utilization Rate
Fuel	mpg	mpg
Tires	miles of life	miles of life
Oil	mpq	mpq

Figure 2

Operator's LCC Data and Evaluation Results

Current Fleet Unit Mat'l Cost Per Event	Oper. Time Per Maint. Event Current Fleet	Time Impact Per Maint. Event	No. of Maint. Events (2 Yrs.)	Material Impact Per Maint.	$ Impact Per Bus Life	$ Impact on Life of (No.)-Bus Buy
0	168 minutes	168 min.	36	0	$ 80	$ 2,960
0	300 minutes	129 min.	124	0		7,807
0	210 minutes	210 min.	272	0	3,093	818,565

$ Impact Per Bus Life	$ Impact on Life of Bus Buy
$	$
$	$
$	$

(continued)

Calculations play an important part in the operator's evaluation process. They too should be well recorded. It is therefore suggested that these calculations be recorded as shown in "Sample Calculations," Figure 3, pages E-15 and E-16.

Sample Calculations

Elimination of 3,000-mile intervals for preventive maintenance inspections

Basic Data

Bus Life	500,000 miles
Fleet Size	68 buses
Bus Buy	205 buses
Average Bus Mileage over 6 Months	24,014 miles
Labor Rate	$13.70 per hour (burdened)
No. of 3,000-Mile Inspections over 6 Months	272
ADB 3,000 Mile Inspection Time	0 minutes
Operator 3,000-Mile Inspection Time	210 minutes

Calculations

Inspection time saving per 3,000-mile inspection = 210 minutes - 0 minutes = 210 minutes

Inspection time saving per fleet per 6 months = $\frac{210 \text{ min.} \times 272}{60 \text{ minutes}}$ = 952 hours

Ratio: bus life/data sample period = $\frac{500{,}000 \text{ miles}}{24{,}014 \text{ miles/6 mos.}}$ = 20.82

Inspection time savings per bus per 6 months = $\frac{952 \text{ hours}}{68 \text{ buses}}$ = 14 hours

Inspection time savings per bus life = 14 x 20.82 = 291.48 hours

$ savings per bus life = 291.48 hours x $13.70 = $3,993

$ savings over life of 205-bus buy = $818,565

Remove, repair, and replace air conditioning fan motor

Basic Data

Bus Life	500,000 miles
Fleet Size	103 buses
Bus Buy	37 buses
Average Bus Mileage over 2 Years	53,333 miles
Labor Rate	$8.71 per hour (burdened)
No. of Maintenance Events over 2 Years	36
ADB Removal, Repair, and Replacement Time	0 minutes (A/C motor eliminated)
Operator Removal and Replacement Time	168 minutes

Figure 3

Calculations

Removal, repair, and replacement time saving per event = 168 minutes - 0 minutes = 168 minutes

Time savings per fleet per 2 years $= \frac{168 \text{ min. x } 36}{60 \text{ min.}} = 100.8$ hours

Time saving per bus per 2 years $= \frac{100.8 \text{ hrs.}}{103 \text{ buses}} = 0.98$ hours

Ratio: bus life/data sample period $= \frac{500{,}000 \text{ miles}}{53{,}333 \text{ miles/2 yrs.}} = 9.37$

Time saving per bus life = 0.98 hours x 9.37 = 9.18 hours
$ savings per bus life = 9.18 x $8.71 = $79.95
$ savings over life of 37-bus buy = $80 x 37 = $2,960

Remove and replace transmission oil cooler

Basic Data

Bus Life	500,000 miles
Fleet Size	103 buses
Bus Buy	37 buses
Average Bus Mileage over 2 Years	53,333 miles
Labor Rate	$8.71 per hour (burdened)
No. of Maintenance Events over 2 Years	5
ADB Removal and Replacement Time	103.5 minutes
Operator Removal and Replacement Time	62.0 minutes

Calculations

Removal and replacement time loss per event = 103.5 minutes - 62.0 minutes = (41.5 minutes)

Additional labor cost per maintenance event $= \frac{(41.5 \text{ min.}) \text{ x } \$8.71\text{/hr.}}{60 \text{ min.}}$ = ($6.01)

Additional labor cost per fleet per 2 years = ($6.01/event) x 5 events = ($30.05)

Ratio: bus life/data sample period $= \frac{500{,}000 \text{ miles}}{53{,}333 \text{ miles/2 yrs.}} = 9.37$

Additional labor cost per fleet life = ($30.05) x 9.37 = ($281.57)

Additional labor cost per bus life $= \frac{(\$281.57)}{103 \text{ buses}} = \$2.73 \quad \$3$

Total additional maintenance cost per 37-bus buy = ($3) x 37 = ($111)

Figure 3 (continued)