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A FLEET MANAGER'S GUIDE TO TESTING VEHICLES FOR VALID RESULTS

Prepared for

U. S. Department of Energy

Assistant Secretary for
Conservation and Solar Applications
Office of Transportation Programs
Washington, D. C. 20545

MASTER

February 1981

Alternative
Fuels
Utilization
Program

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for

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Conservation and Solar Applications
Office of Transportation Programs
Washington, D. C. 20545
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I. FOREWORD

This document was prepared under contract to the U.S. Department of Energy, Office of Transportation Programs, Alternative Fuels Utilization Branch and was provided, in conjunction with an oral presentation, to participants in the DOE Conference on Fleet Use of Unique Automotive Fuels, August 13-14, 1980, San Antonio, Texas. The intent of that conference was to provide an educational forum where recent experiences in the fleet use of alcohol/gasoline blend fuels could be shared with those interested in operating fleets on such fuels. In addition, the conference scope included sessions on Governmental policy aspects related to emergency preparedness in the event of a severe petroleum shortage, and data on the emergency use of off-specification fuel formulations.

The conference concluded with a workshop titled "How To Test Fleet Vehicles For Valid Results" which was conducted by Mueller Associates, Inc., Consulting Engineers. That workshop was intended, as this guidebook is, to provide fleet operators/managers with an elementary approach to evaluating concepts which may appear to offer fuel and/or cost savings in vehicle fleets. Subsequent to the conference, it was decided by the DOE to publish this guidebook as a DOE document so that it might be more widely available to interested parties.

II. INTRODUCTION

The managers of automotive fleets are vitally interested in saving money. Fleet procurement and operations costs are increasing rapidly. Fuel cost increases have been especially extreme. Conservation measures have included the purchase of more fuel-efficient vehicles, consolidation or reduction of unnecessary or redundant travel, upgraded and/or more frequent vehicle inspection, maintenance, repair, and the installation of fuel-saving components (or removal of fuel-consuming components).

Virtually every significant cost saving measure has a cost associated with it, either a tangible financial cost, or an intangible (convenience) cost. In order to justify to his superiors that such measures should be taken, the fleet manager must be able to demonstrate clearly that the benefits derived from implementation of these measures will exceed the costs of doing so. In order to accomplish this, he must have unambiguous measures of both costs and benefits and methods of comparison which are easily usable and which yield unambiguous results. The analysis methods presented in this document are designed to accomplish this end.

The typical fleet manager must deal with a wide variety of costs including: new vehicle acquisition, maintenance, insurance, and fuel. These costs are rising rapidly and will probably continue to do so for the foreseeable future. In order to reduce costs, or at least to reduce the rate at which they are increasing, the prudent fleet manager will investigate any potential means to save fuel or other costs. Typical fleet objectives are shown in Table II-1:

TABLE II-1: TYPICAL FLEET MANAGEMENT OBJECTIVES

- Reduced Fleet Fuel Use
- Reduced Downtime
- Longer Vehicle Life
- Reduced Maintenance Costs
- Safer Driving Practices
- Improved Vehicle Resale Value
- Minimized Overall Fleet Costs

Potential methods employed to achieve these objectives are shown in Table II-2:

TABLE II-2: TYPICAL COST-SAVING MEASURES FOR FLEETS

- Radial-Ply Tires/Increased Tire Pressure
- Fuel-Efficient Lube Oils
- High-Efficiency Air Conditioner Compressors
- Route Optimization
- Speed Reduction
- Driver Efficiency Training
- Engine/Drivetrain Modifications
- Combustion Improvers
- High Energy Ignition Systems
- Weight Reduction
- Add-On Aerodynamic Devices
- Fuel Substitutes (Propane, etc.)
- More Frequent Inspections/Tuneups
- Thermo-Cycling Fans
- Engine Derating

It is apparent that most fleet cost-saving measures center on, or are associated with reduced fuel use.

Assuming that a fleet manager has prepared such a "shopping list" which is compatible with his fleet operations, he will desire to know how he should rank these items in order of their economic value and technical feasibility. Once he has accomplished this, he must prepare an implementation plan for approval by the fleet administrator. The plan must delineate costs and projected savings. In this way, the necessary investment costs can be justified. While the savings potential of some of these items is well established, others have not been proven or may not apply to a specific fleet due to operational particulars.

One of the best ways to establish costs and obtain accurate savings estimates of these questionable items is by limited testing within the working fleet. Then, it is not necessary to accept blindly the savings claimed by equipment or service suppliers. Testing allows claims of fuel saving or cost saving to be verified with a minimum investment risk. While the measurement of other costs such as acquisition, maintenance, and insurance costs is relatively straightforward and amenable to standard cost accounting procedures, the measurement and extrapolation of fuel use (and costs) from limited test programs involves many subtleties which, if ignored, can lead to erroneous conclusions.

The information presented in this document is designed to allow a typical fleet manager to set up a fleet test program and to interpret the results. While it is aimed primarily at the measurement and estimation of fleet fuel economy and fuel use, it is relatively easy to add other areas of economic interest. Section III explains how to set up a vehicle test program, Section IV deals with the collection and analysis of data from such tests

and Section V suggests methods of reporting results. Section VI offers an explanation for performing life cycle cost analyses, the final step in evaluating the cost effectiveness of the device, system, revised maintenance practice, etc. that was tested and shown to offer an incremental cost or fuel savings.

III. TEST PROCEDURES

Assume that a fleet manager has decided to try to reduce operating costs and has prepared a list of one or more changes which he would like to test on a limited scale so that he can justify the cost of such changes to his superiors. He must design and conduct a test which will yield meaningful results. All too often, a poorly prepared test will yield inconclusive or erroneous results which may mean the loss of a potentially promising fleet improvement or worse, the adoption of measures which actually increase rather than decrease costs. The proper preparation, execution, and interpretation of a fleet test is crucial to avoiding such mistakes. The topics presented below are designed to acquaint the typical fleet manager with the necessary elements of a good test program and some of the pitfalls to avoid. Table III-1 presents the two principal types of fuel economy tests and the advantages and disadvantages of each.

TABLE III-1. TYPES OF FUEL ECONOMY TESTS

<u>Name</u>	<u>Description</u>	<u>Advantages</u>	<u>Disadvantages</u>
Paired Tests	Each vehicle is first tested in stock (original) condition. It is then modified to incorporate the (claimed) improvement and retested.	Since each vehicle receives the test treatment, the maximum number of vehicles is treated. This increases the statistical resolving power (or validity) of test results.	External factors (weather, driving cycle, vehicle age, etc.) may be different after the vehicles are modified.
Unpaired Tests	The test fleet is divided into two or more subfleets. Each subfleet receives a different modification (one is unmodified to act as a control group).	Since the treatment and control subfleets are operated at the same time, external influences (weather, driving cycle, vehicle age, etc.) are minimized.	In order to yield significant results, the two or more subfleets must be chosen to be as similar to each other as possible. Otherwise, the results may be biased.

o TEST PLAN

Before a test is started it is vitally important that a written, formal test plan be prepared. This plan should be prepared in sufficient depth and clarity to allow anyone knowledgeable of fleet operations to conduct the test. This is especially important for longer-term tests where employee turnover and occasional absence of key personnel must be considered. Everything of substance must

be written down before the test begins, where possible. The information presented below should be determined.

In preparing the test plan, one must ask - "What is the purpose of this test?" This may sound like a simple question, but if it is not carefully considered, significant waste of money, time, and other resources may result. Above all, the test objective must be unambiguous; it must mean the same thing to all individuals involved. Assume for example that the economic value of radial tire use is to be determined by the test. There are two direct economic advantages claimed for radial-ply tires: extended life and reduced rolling resistance (which can save fuel). Both of these factors must be measured for meaningful economic results.

It is also necessary that the test objective place a limit on the results expected. A test which tries to measure too many effects will often yield confusing results if some of the effects interact with each other. Also, the inclusion of too many test objectives often leads to compromises in the test procedure which reduce the significance with which any single objective can be measured.

As an example, assume that a fleet manager wishes to determine the cost savings of switching to radial-ply tires from bias-ply belted tires. There are three direct cost and cost saving elements which must be considered: increased acquisition costs, improved tread life, and reduced fuel use. Radial tires generally cost more than equivalent size bias-ply belted tires. However, they usually last longer and exhibit a lower rolling resistance which can yield a fuel savings. In order to test these claims in his fleet's environment, the fleet manager chooses two representative vehicles. One he equips with new bias-ply belted tires of the same type he currently uses on most of the other fleet vehicles. The other he equips with radial-ply tires. His concern in this test is with differences in first cost, tread life, and fuel used. He then runs the vehicles in normal fleet operation and records the fuel economy of each. He also measures tread depth periodically so that he can estimate the approximate tread life without waiting until the tires are worn out. At the end of a given period (probably one year or more), he is in a position to determine whether the radial tires yield savings which exceed the original cost difference. However, if he is not careful, the test could yield erroneous results. He must assure that the test vehicles are equivalent to each other in all important aspects other than the type of tires used. Otherwise, the effects he will be measuring will be caused in part by factors other than the one he is testing. The careful elimination of all potentially biasing factors is considered in the following sections.

o TEST FLEET CHARACTERIZATION AND CONTROL

For large fleet operations, it is often neither feasible nor desirable to include all of the fleet vehicles in the test program. In some cases, testing only one or two vehicles may prove sufficient. It is important, however, that the vehicles chosen for testing be representative of the entire fleet. It would not be advisable, for instance, to conduct a radial-ply tire test on pickup trucks if the majority of the fleet were sedans. Similarly, the test vehicles should reflect the typical age, mileage, and duty cycle of the fleet. Where a fleet has significant numbers of grossly disparate vehicles (heavy trucks and compacts, for instance) the test should include representatives of each group.

Tests conducted over an extended period (usually one year or more) often encounter vehicle turnover problems (wear-out, scheduled trades, accidents). Vehicle turnover can lead to incomplete tests and should be avoided or accounted for, if possible. It is usually advisable to allow for unplanned vehicle turnover by including more vehicles in the test than would otherwise be necessary. The excess number depends on fleet experience, the number of test vehicles needed, and the length of time over which the test is to be conducted.

The minimum number of vehicles to be tested depends upon the expected results and the expected variation of results between vehicles. This subject will be treated in detail in Section IV under Data Collection and Analysis Procedures.

o SELECTION OF DRIVERS

As with vehicles, test drivers should be selected to be representative of typical drivers in the fleet. The attitudes and driving procedures of vehicle drivers can exert substantial effects upon most test results. Therefore, the test drivers should be objective, cooperative, and interested in helping to conduct a good test. In addition, test drivers should have low turnover rates, if possible, to reduce retraining time and cost and increase test uniformity. Where possible, the drivers should be given a thorough pre-test orientation. Their comments concerning the test procedure should also be solicited, especially when the test is to be conducted in the normal working environment. It is essential that the operational test procedures required of the driver not interfere with his normal duties and vice versa.

o INSPECTION, MAINTENANCE AND REPAIR ACTIVITIES

While all vehicles will need some maintenance and repair during their lifetimes, it is important that such needed activities not interfere with test requirements and vice versa. For example, a broken odometer will prevent the determination of fuel economy. Plans for quick repair of important malfunctions should be made, otherwise, valuable and expensive test data will be lost. Vehicle

malfunctions related to the engine or drivetrain must be carefully recorded and dated. For example, the detection of an inoperative exhaust gas recirculation (EGR) valve halfway through a test should immediately cast doubt on any fuel economy or emission data collected to that point. Similarly, any engine or transmission failure or deficiency should also be noted.

Representative vehicle components to be inspected and problems to be noted before, during and after a test are shown in Table III-2:

TABLE III-2: VEHICLE INSPECTION AND DIAGNOSIS AREAS

- Engine
 - Ignition Timing
 - Compression
 - Idle Speed
 - Oil Leakage
 - Exhaust Smoke
 - Emissions
 - Performance
 - Thermostat Function
- Transmission/Differential
 - Shift Points
 - Noise
 - Fluid Leakage
 - Slippage
- Wheels and Tires
 - Bearing Adjustment
 - Brake Drag
 - Bent Wheels
 - Dynamic Balance
 - Excessive Tire Wear
 - Over/Under-Inflation
 - Out-of-Roundness
 - Wheel Alignment
- Accessories and Accessory Drives
 - Drive Belts
 - Pulleys
 - Alternator
 - Power Steering
 - Air Conditioning

While many of these items, taken singly, exert only a small effect on fuel economy, several in combination can and do result in substantial effects. This may bias the test results, cause greater test variability and reduce the significance of any results. It is important that all vehicles used in the test program be as close to "stock" condition as possible, with all components operating properly.

○ FUEL CONTROL

Most contemporary fleet vehicles are fueled with either gasoline or light distillate (Diesel) fuels. The energy content of these fuels can vary substantially with season (due to various additives), refinery source and processing changes, and crude oil source. It is not unusual to find energy content variations of several percent in two different fuel deliveries. It is therefore important that fuel quality be maintained at a constant condition throughout the

test. Fuel energy content is not normally a required specification for highway vehicles and is therefore not usually controlled directly. The easiest and a reasonably accurate method for assuring uniform energy content is with a specific gravity test. For good test results, fuel specific gravity should not vary by more than plus or minus one percent during the test. This is often achieved by using the same fuel supply for the whole test. If this is impractical, specific gravity measurements should be made periodically (weekly or monthly). Where a test spans more than one season, it is sometimes necessary to accept changes in fuel energy content which are necessary to improve cold/hot starting capabilities. Care should then be taken to assure that all test vehicles are receiving the same fuel at any given time, even though the fuel characteristics may be changing over time. This may increase the variation in test results, however.

The type of fuel, supplier, brand name and test results (if any) should be permanently recorded in a log book. This information may later be of value in explaining test results. Where water contamination is a potential problem (with gasoline/alcohol blends, for instance), tests for fuel water content should also be conducted.

All gasolines and many light distillate fuels tend to degrade during storage, forming gums, organic acids, sludges and other undesirable compounds. The rate at which these fuels degrade depends upon many factors including the initial crude oil stock, the refining processes, and the type of storage tank used (iron acts as a catalyst for some of these reactions). Generally, it is not advisable to store such fuel for more than three months. Storage for one year or longer has been accomplished within acceptable degradation limits, but not always consistently.

Delivery of the fuel to the vehicles must be carefully measured since this constitutes one of the two measurements needed to determine fuel economy. Dispensing pumps must be accurately calibrated if good results are to be obtained. If the test fleet is to use commercial filling stations, such pumps are inspected and certified by the state and should be reasonably accurate. If possible, however, each test vehicle should use only one pump throughout the test to further reduce variations. If a private pump is used, it should be calibrated by experienced personnel immediately before and after the test. The calibration values should be permanently recorded for use during test data analysis. In addition, spot calibration tests should be run during the test program to assure that a pump malfunction has not occurred.

Vehicle fueling should be accomplished in a uniform manner. The fueling location should be as level as possible and the test vehicles should be parked in the same position each time. This will reduce the tank-to-tank variations normally experienced during uncontrolled fueling and generally improve the quality of the data.

Remember that the vehicle must end the test with the same amount of fuel in its tank as when it began. It is advisable to start and end the test with a full tank. Therefore, the amount of fuel required to fill the tank at the beginning of the test is not part of the test and should not be included in the data analysis.

o CONTROL OF EXTRANEIOUS FACTORS

Tests which are conducted with a working fleet are, of course, subject to the constraints imposed by the tasks which must be accomplished. Changes in these tasks during the test can cause fuel economy changes. Periods when substantial fleet operation changes are known to occur should be avoided where possible. For example, a vehicle fleet at a university would be operated differently during summer recess. If such periods cannot be avoided, a means must be devised to compensate for such changes, possibly by extending the test program through two such periods for "before" and "after" testing.

Weather can also have a strong influence on fuel economy. Seasonal variations of temperature, winds, rain and snow can result in fuel economy changes of ten percent or more. Therefore, the test program must be scheduled so as to avoid biasing the test results by seasonal weather influences. Short term tests lasting days or weeks can also be confounded by short term weather extremes, which are often unpredictable. Weather measurements (maximum or average daily temperature, wind speed, rain, snow, etc.) should be recorded or obtained from the local weather bureau. This information may be used later to account for the weather effects in the fuel economy results.

IV. DATA COLLECTION AND ANALYSIS PROCEDURES

o DATA COLLECTION, STORAGE, AND RETRIEVAL

The most essential element of any test is accurate and comprehensive data. A good general rule to follow is "When in doubt, write it down." All records of fuel purchases, odometer readings, maintenance tasks, weather and driver/vehicle changes must be recorded promptly and stored for future access. Fuel consumption and mileage are usually recorded in a log book kept with the vehicle. The driver is required to record the amount of fuel delivered to the vehicle and the odometer reading. Any other information concerning changes in vehicle performance, weather or driving cycle should also be recorded by the driver at this time. The date of the record and the initials or name of the driver should also be recorded.

On a periodic basis, usually every week or month, the driver should transfer these data to a central storage area. Frequent transfer of raw data tends to reduce the amount of information lost through carelessness. The data storage area should be relatively secure to prevent inadvertent loss. Lockable filing cabinets are sufficient. Each vehicle should have its own file folder in the storage area. Each file should be maintained in chronological order to facilitate later analysis.

o DATA ANALYSIS

Fuel and mileage data are aggregated in the following way: For each vehicle, the total test mileage is divided by the total amount of fuel used. If it is a paired test, this should be done separately for each phase of the test. The figures obtained are the average test fuel economies of the vehicles. While fuel economy is a useful measure of the performance of a single vehicle, it cannot be used to determine an average effect for more than one vehicle. This can be shown by the following example. Assume that two test vehicles achieve average test fuel economies of ten miles per gallon and thirty miles per gallon, respectively. Using a straight averaging technique, we would say that the average fleet fuel economy for the two vehicles was:

$$\frac{10 + 30}{2} = 20 \text{ miles per gallon}$$

However, this answer is incorrect if we assume that each vehicle travels that same distance during the test. This is shown in Table IV-1.

TABLE IV-1: COMPUTATION OF AVERAGE FUEL ECONOMY
FOR MULTI-VEHICLE FLEETS

	<u>Vehicle 1</u>	<u>Vehicle 2</u>
Fuel Economy	10 mpg	30 mpg
Distance Traveled	1,000 miles	1,000 miles
Fuel Consumed	100 gallons	33.3 gallons
<hr/>		
Total Distance Traveled	2,000 miles	
Total Fuel Consumed	133.3 gallons	
<hr/>		
Average Fleet Fuel Economy	$\frac{2,000}{133.3} = 15 \text{ miles per gallon}$	

If we had used the simple average fuel economy value of 20 miles per gallon, we would have estimated the fuel used for the fleet to travel 2,000 miles at 100 gallons, a 25 percent error. It is usual to assume that each fleet vehicle will travel the same distance as every other fleet vehicle. To do otherwise is to assume that certain vehicles are inherently different. This may be the case if the fleet is composed of disparate vehicles (dump trucks and compacts, for instance). In such cases, it is advisable to separate the fleet into two or more subfleets and to analyze each of the subfleets separately. The only instance in which the simple average fleet fuel economy yields a correct answer is when each vehicle consumes the same amount of fuel. This is not a reasonable assumption, in general, since vehicles are not operated to consume fuel; rather, fuel is consumed in order to "produce" miles of travel. Therefore, the assumption of equal miles traveled implies that each vehicle in the fleet (or subfleet) is of equal value in its ability to provide service (i.e., miles of travel). The average fleet fuel economy assuming equal miles traveled is obtained in the following manner:

[a]

- Determine the average test fuel economy of each vehicle.
- Invert these figures to obtain the average test fuel consumption rate (gallons per mile) of each vehicle.
- Determine the simple average fleet fuel consumption rate.
- Invert the average fleet fuel consumption rate to obtain the average fleet fuel economy.

For the example of Table IV-1:

Vehicle #1: 10 miles per gallon = 0.10 gallons per mile

Vehicle #2: 20 miles per gallon = 0.033 gallons per mile

Average fleet fuel consumption rate:

$$= \frac{0.10 + 0.033}{2} = 0.0667 \text{ gallons per mile}$$

Average fleet fuel economy:

$$\frac{1}{0.0667} = 15.0 \text{ miles per gallon,}$$

which agrees with the value determined earlier.

o STATISTICAL ANALYSIS PROCEDURES

The statistical analysis procedures presented below are designed to be usable by individuals who are not familiar with statistical concepts. It should be noted that these are not the only statistical analysis procedures available, only the easiest to understand and use. More powerful procedures are also available, but cannot be adequately explained in the limited space available.

Statistical analysis is the term used to describe the mathematical process of making generalizations about a large population of things based on measurements of a small sample from the population. For example, when the Department of Health and Human Services must determine the average weight of an American adult male, it does not do so by weighing all the men in the country, it picks a random sample of men and determines the average weight. Intuitively, we can see that the greater the number of men in the sample, the closer will be the sample average to the true population average. However, as long as the sample size is smaller than the entire population, the resulting figure will not be exactly correct. Using the methods of statistical analysis, however, we can estimate the weight range within which the population average probably lies. To do this we must know the sample average and another value, S, the standard deviation of the sample. Essentially, the standard deviation is a measure of the diversity of the measurements. If the weights of all the men in the sample were identical, the standard deviation would be zero. The standard deviation is determined in the following manner:

Consider the following values obtained by weighing three randomly chosen men:

$$\begin{aligned} y_1 &= 190 \text{ lb.} \\ y_2 &= 210 \text{ lb.} \\ y_3 &= 188 \text{ lb.} \end{aligned}$$

The average sample weight is: $\frac{190 + 210 + 188}{3} = 196 \text{ lb.} = \bar{y}$

The sample standard deviation is:

$$s = \sqrt{\frac{(y_1 - \bar{y})^2 + (y_2 - \bar{y})^2 + (y_3 - \bar{y})^2}{n-1}} =$$
$$s = \sqrt{\frac{(190 - 196)^2 + (210 - 196)^2 + (188 - 196)^2}{3-1}} = 12.2 \text{ lb.}$$

We now know that the average weight of the three-man sample is 196 lb. and that the standard deviation is 12.2 lb. By using Table IV-2 and Equation (1) below, we can determine the probable range of the average weight of the population:

$$\text{Weight Range} = \pm \frac{t \times S}{\sqrt{n}}$$

where t is obtained from Table IV-2

S is the standard deviation

n is the sample size

From Table IV-2, we can see that for a sample size of 3 and assuming we wish to be 90 percent certain of including the population average, we must use a "t" value of 2.920. Therefore, the weight range is:

$$\pm 2.920 \frac{12.2}{\sqrt{3}} = \frac{35.624}{1.73205} = \pm 20.6 \text{ lb.}$$

Therefore, we can estimate, with at least 90 percent certainty that we are right, that the average weight of the population of American adult males is: 196 lb. $\pm$ 20.6 lb., or from 175.4 lb. to 216.6 lb. This is obviously not a very good estimate; it is much too wide to be useful. We can decrease this width by using a larger sample. For example, if our sample had included 100 men, but had yielded the same average value and standard deviation, the range would be:

$$\pm 1.645 \text{ (from Table IV-2)} \frac{12.2}{\sqrt{100}} = \pm 6.3 \text{ lb.,}$$

and we would estimate the range within which the true population lies (with 90% confidence) as 196 lb. $\pm$ 6.3 lb. or 189.7 lb. to 202.3 lb. This is a much more usable and meaningful result.

TABLE IV-2: t VALUES FOR STATISTICAL TESTS

Sample Size	Confidence Value				
	80%	90%	95%	98%	99%
2	3.078	6.314	12.706	31.821	63.657
3	1.886	2.920	4.303	6.965	9.925
4	1.638	2.353	3.182	4.541	5.841
5	1.533	2.132	2.776	3.747	4.604
6	1.476	2.015	2.571	3.365	4.032
7	1.440	1.943	2.447	3.143	3.707
8	1.415	1.895	2.365	2.998	3.499
9	1.397	1.860	2.306	2.896	3.355
10	1.383	1.833	2.262	2.821	3.250
11	1.372	1.812	2.228	2.764	3.169
12	1.363	1.796	2.201	2.718	3.106
13	1.356	1.782	2.179	2.681	3.055
14	1.350	1.771	2.160	2.650	3.012
15	1.345	1.761	2.145	2.624	2.977
16	1.341	1.753	2.131	2.602	2.947
17	1.337	1.746	2.120	2.583	2.921
18	1.333	1.740	2.110	2.567	2.898
19	1.330	1.734	2.101	2.552	2.878
20	1.328	1.729	2.093	2.539	2.861
21	1.325	1.725	2.086	2.528	2.845
22	1.323	1.721	2.080	2.518	2.831
23	1.321	1.717	2.074	2.508	2.819
24	1.319	1.714	2.069	2.500	2.807
25	1.318	1.711	2.064	2.492	2.797
26	1.316	1.708	2.060	2.485	2.787
27	1.315	1.706	2.056	2.479	2.779
28	1.314	1.703	2.052	2.473	2.771
29	1.313	1.701	2.048	2.467	2.763
30	1.311	1.699	2.045	2.462	2.756
inf.	1.282	1.645	1.960	2.326	2.576

If we needed even greater accuracy we would have to increase the sample size further.

In a similar way, statistical analysis can be used to estimate the average fuel consumption rate of a fleet of vehicles, based on a limited sample.

For example, assume that ten vehicles are tested for one month and that the following data are obtained:

<u>Vehicle</u>	<u>Miles</u>	<u>Gallons</u>	<u>Miles Per Gallon</u>	<u>Gallons Per Mile</u>
1	805	37.8	21.3	0.047
2	960	49.5	19.4	0.052
3	990	35.7	22.1	0.045
4	920	51.7	17.8	0.056
5	1,110	52.1	21.3	0.047
6	891	43.5	20.5	0.049
7	640	29.8	21.5	0.047
8	1,202	52.3	23.0	0.043
9	793	40.1	19.8	0.051
10	921	43.0	21.4	0.047

Average Fuel Consumption Rate = 0.0484 gallons per mile
Standard Deviation = 0.00375 gallons per mile

Assuming a 90 percent confidence is desired for a sample of ten vehicles, the probable range of the average fuel consumption rate for the population is:

$$\pm 1.833 \text{ (Table IV-2, } n = 10, 90\% \text{ confidence)} \frac{0.00375}{\sqrt{10}} =$$

$$\pm 0.00217 \text{ gallons per mile}$$

Therefore, the 90 percent confidence interval is:

from: $0.0484 - 0.00217 = 0.04623$ gallons per mile
to : $0.0484 + 0.00217 = 0.05057$ gallons per mile

Inverting these values yields an average fleet fuel economy range of 19.8 to 21.6 miles per gallon. Note that this range applies to the entire fleet which may be hundreds of vehicles, based on the results of a ten vehicle test. If greater accuracy is required, the sample size must be increased.

When a paired test is conducted, it is much more accurate to deal with changes in fuel consumption rates. For example, assume that ten vehicles are tested, first in stock condition and then with a (claimed) energy conserving device installed. Assume the following results are obtained:

TABLE IV-3: HYPOTHETICAL RESULTS FROM A PAIRED
FUEL ECONOMY TEST

Car	Stock Condition (1)		With Device (2) Installed		Fuel Consumption Rate Ratio (2)/(1)
	Miles Per Gallon	Gallons Per Mile	Miles Per Gallon	Gallons Per Mile	
1	21.2	0.0472	21.5	0.0465	$\uparrow \frac{0.0465}{0.0472} = 0.985$
2	19.8	0.0505	20.3	0.0493	0.976
3	19.5	0.0513	19.4	0.0515	1.004
4	20.8	0.0481	20.9	0.0478	0.994
5	21.5	0.0465	23.3	0.0429	0.923
6	22.1	0.0452	21.9	0.0457	1.011
7	20.1	0.0498	22.1	0.0452	0.908
8	18.3	0.0546	19.5	0.0513	0.940
9	19.9	0.0503	20.5	0.0488	0.970
10	21.1	0.0474	22.2	0.0450	0.949
					Average = 0.966 Standard Deviation = 0.0348

The 90 percent confidence range of the average fuel consumption rate ratio is:

$$\pm 1.833 \text{ (Table IV-2, } n = 10, \text{ confidence} = 90\%) \frac{0.0348}{\sqrt{10}}$$

$$= \pm .02017$$

Therefore, the average fuel consumption rate ratio for the entire fleet is expected to be within the range 0.966 ± 0.0217 or from 0.9443 to 0.9877. This means that, on the average, the typical fleet vehicle should consume less fuel (from 94.4% to 98.77% of "stock" condition) with the fuel-saving device installed. Or, considered differently, it is expected that the average fleet vehicle will experience a fuel economy increase of from:

$$\frac{1}{0.09877} = 1.012 \text{ or } 1.2 \text{ percent to } \frac{1}{0.09443} = 1.059 \text{ or } 5.9 \text{ percent.}$$

If an unpaired test is conducted, it is not possible to analyze the results by calculating fuel consumption rate ratios since none of the vehicles is tested in both stock and modified conditions. In this case, it is necessary to use a different statistical test concerning whether the two samples (stock and modified) can be said to be drawn from different populations; in other words, whether the effects of the modification are significant.

Consider the following hypothetical example of an unpaired fuel economy test in Table IV-4:

TABLE IV-4: HYPOTHETICAL RESULTS OF AN UNPAIRED FUEL ECONOMY TEST

<u>Car</u>	<u>Stock Condition</u>		<u>Modified Condition</u>	
	<u>MPG</u>	<u>GPM</u>	<u>MPG</u>	<u>GPM</u>
1	20.1	0.0498	---	---
2	17.3	0.0578	---	---
3	17.9	0.0559	---	---
4	19.2	0.0521	---	---
5	19.5	0.0513	---	---
6	---	---	21.3	0.0469
7	---	---	22.1	0.0452
8	---	---	24.1	0.0415
9	---	---	21.3	0.0469
10	---	---	22.4	0.0446

The average fuel consumption rates and standard deviations of the stock and modified vehicles are:

Stock (1): Average Fuel Consumption Rate = 0.0534 (18.72 mpg)
Standard Deviation = 0.0033

Modified (2): Average Fuel Consumption Rate = 0.04502 (22.21 mpg)
Standard Deviation = 0.0022

The standard deviations are averaged in the following way:

$$\begin{aligned}\bar{S} &= \sqrt{\frac{(n_1-1) S_1^2 + (n_2-1) S_2^2}{n_1 + n_2 - 2}} \\ \bar{S} &= \sqrt{\frac{(4) (0.0033)^2 + (4) (0.0022)^2}{5 + 5 - 2}} \\ \bar{S} &= 0.00280\end{aligned}$$

The t value is determined from Table IV-2 based on $n = n_1 + n_2 - 1$

In this test we estimate the difference in fuel consumption rate:

Modified - Stock = 0.04502 - 0.0534 = -0.00838 gallons per mile

$$\begin{aligned}\text{Range} &= \pm t \times \bar{S} \sqrt{\frac{1}{n_1} + \frac{1}{n_2}} \\ &= \pm 1.860 \times 0.00280 \sqrt{\frac{1}{5} + \frac{1}{5}} \\ &= \pm 0.00329 \text{ gallons per mile}\end{aligned}$$

or from: 0.00838 - 0.00329 = + 0.00509 gallons per mile

to : 0.00838 + 0.00329 = +0.01167 gallons per mile

This means that changing from the stock to the modified status will result in a reduction of fuel use by from 0.0051 gallons per mile to 0.012 gallons per mile of fleet travel. If the fleet travels one million miles per year, the expected fuel savings would be from 5,100 gallons to 12,000 gallons per year or from about 10 to 22-percent of the total fuel previously used.

o SOME FINAL WORDS ON THE VALUE AND LIMITATIONS OF STATISTICAL ANALYSIS

Statistical analysis is a strong tool for determining whether or not test results are significant or meaningful. It also allows the user to objectively quantify the degree of certainty he has in a given set of results. However, there are several cautions which apply whenever a statistical analysis is attempted:

- (1) In order for the analysis to be valid, the frequency distribution of the measurements must be bell-shaped (more correctly, the data must form a normal distribution). This is more often true than not for fuel economy tests, but the data to be analyzed should be reviewed to make sure that another distribution is not possible.
- (2) The analysis assumes that all external factors which could bias the result have been eliminated or accounted for. In the case of paired tests, extreme weather, temperature, and driving cycle differences between the stock and modified test phases must be avoided. In the case of the unpaired tests, the subfleet vehicles (stock and modified) must be randomly chosen and be as similar to each other as possible in terms of vehicle type and driving.
- (3) If the statistical test predicts a population range which includes zero (zero difference between the stock and modified groups), then it can be said that the test does not support the assumption that a non-zero effect exists. However, such a result does not prove that there is no effect. The lack of proof of a non-zero effect might just as easily be due to a poorly-controlled test. Perhaps this is more easily understood in an analogy to a courtroom trial. The accused (i.e., the parameter of interest, such as fuel consumption) is presumed innocent (i.e., that there is no difference) until he is proven guilty (i.e., that there is a difference). A "not guilty" verdict (i.e., failure to prove an effect) only means that the prosecution has failed to prove guilt. It does not mean that the accused is innocent. In the same way, failure to prove that an effect exists does not mean that the effect does not exist.

V. REPORTING TEST RESULTS

Once a test has been completed, analyzed, and conclusions drawn (if possible), a final report should be prepared. The final report should include a statement as to the purpose and objective of the test, a copy of the test procedure (the procedure actually used, which is not necessarily the procedure written before the test began), a copy of the raw data (if not too voluminous), sample calculations, any pertinent observations, results and conclusions. The report should be complete enough so that a technical or semi-technical person can read it and understand everything that was done. Often, the final report becomes the only written document which exists within a year or two after the test is completed. It is unfortunate that much valuable information is often lost when a formal final report is not issued because it takes "too much time and money" to prepare.

VI. LIFE CYCLE COST ANALYSIS FOR FLEET VEHICLES

o BACKGROUND

In the not-too-distant past, it was commonly held that the cost of fueling fleet vehicles was of secondary importance when vehicle purchase and maintenance decisions were made. Today the cost of fuel to operate a fleet vehicle over its lifetime can equal or even exceed its purchase price. In the near future, fuel costs will comprise half to two-thirds of the total owning and operating cost of the typical fleet automobile. Under these circumstances, the prudent fleet owner and administrator will consider fleet investments based on life cycle costs rather than on the basis of first or acquisition costs.

Life cycle cost analysis is a method by which all costs associated with owning and operating a fleet vehicle (purchase price, fuel, maintenance and repair, insurance, parking, tolls, etc.) can be reduced to a single figure. This figure can then be compared among several vehicle choices to determine which has the lowest life cycle cost. With few exceptions, the vehicle with the lowest life cycle cost should always be the one chosen unless the life cycle cost differences are small, in which case other, non-economic factors may rule.

o LIFE CYCLE COST ANALYSIS PRINCIPLES

The principal facet of life cycle cost analysis is the acknowledgement that money has a value which changes with time. One dollar spent or collected today does not have the same value as one dollar spent or collected one year from now. More specifically, one dollar spent on fuel three years from now is not the same as one dollar spent today partially to purchase the vehicle.

By discounting future costs to their present worth, all cost elements can be reduced to units of equal value. To achieve this, a discount rate must be determined. Generally, this is the annual rate at which money increases in value through investment. For example, a typical citizen may be able to obtain an interest rate of 8 percent (after taxes) on any additional money he may obtain. Therefore, if he invests one dollar today, he will have an investment worth \$1.08 in one year. Conversely, the gain of \$1.08 in one year is equivalent to the gain of \$1.00 today. The discount rate for this individual is therefore 8 percent. Other individuals and organizations may have different discount rates.

The Federal government uses a discount rate of 10 percent. Speculative investors who desire a substantial return on their investments may have a discount rate of 20 or 30 percent or more. Once a discount rate has been chosen, it is a relatively simple

matter to reduce all future incomes and costs to their present worth as follows:

$$PW_i = \frac{C_i}{(1 + r)^n} \quad (1)$$

where:

PW_i = the present worth of cost C_i

C_i = the future cost of Item i

r = discount rate

n = number of years until the realization of cost C_i

For example, assume that a maintenance cost of \$1,000 is expected three years from now. Assume a discount rate of 10 percent. The present worth of this future cost is therefore:

$$PW = \frac{\$1,000}{(1.1)^3} = \frac{\$1,000}{1.331} = \$751 \quad (2)$$

If it is expected that future costs will increase, then an inflation rate (i) must be applied to any future costs which are based on today's prices. If the inflation rate is expected to be 8 percent per annum, the cost of a \$1,000 item (today's prices) in three years would be:

$$\begin{aligned} & 1,000 \times (1.08)^3 \\ & = 1,000 \times 1.260 = \$1,260 \end{aligned} \quad (3)$$

In this case, the present worth would be:

$$PW = \frac{\$1,260}{1.331} = \$947$$

It is apparent that if the discount rate is equal to the inflation rate, the present worth is equal to the future cost and the analysis is a simple summation of all costs. However, this circumstance rarely occurs and should not be lightly assumed. For instance, the cost of gasoline has inflated at an average rate of about 19 percent per year since 1973, much higher than the inflation rate for labor (about 8 percent) or for automobiles and parts (7 percent). Although it is difficult for anyone to predict the inflation rate for these commodities for the future, an attempt must be made. Even the assumption of equal inflation and discount rates in order to simplify the analysis is a prediction, and probably a poor one, judging from the last seven years.

While it is not the purpose of this document to provide an exhaustive treatment of life cycle costing, it is absolutely necessary for the prudent fleet owner or administrator to employ these methods.

Not only can life cycle cost analysis be used to make new vehicle purchase decisions, it can also be used to determine if new vehicles should be purchased at all (as opposed to retaining existing vehicles for additional time). More generally, life cycle cost analysis can also be used to measure the economic differences between any two or more alternatives (the value of an in-house maintenance and repair facility as compared to using an outside contractor, for instance).

o EXAMPLES OF LIFE CYCLE COST ANALYSIS

This section provides an example of life cycle cost analysis. The values presented are for illustrative purposes only. Note that the sample worksheets assume a fuel price of \$1.00 per gallon and also assume the fuel price does not change over the period of interest (3 years). Current economic conditions would indicate a fuel price in the range of \$1.15 to \$1.30 per gallon, depending upon local conditions and whether or not Federal and state fuel taxes must be paid. Also, the inflation rate for fuel prices has averaged about 19 percent per year since 1973. Therefore, to make the analysis more accurate and meaningful, an adjusted fuel price should be used, rather than the current fuel price. This value can be obtained from Table VI-1.

For example:

- o Assume a current fuel price of \$1.30 per gallon.
- o Assume a fuel price inflation rate of 19 percent (same as since 1973) and a 5-year vehicle life.
- o The average fuel price over this period will be:
 $\$1.30 \times 1.74$ (Table VI-1) = \$2.26/gallon

It is obvious that fuel price inflation can have a substantial effect on life cycle cost analysis.

Blank worksheets of the type used in this section's life cycle cost analysis are included in the Appendix. By following the sample calculation with its illustrative (assumed) values, the reader can familiarize himself with the process of life cycle cost computation and try it using figures from his own fleet operation.

TABLE VI-1: FUEL PRICE ADJUSTMENT FACTORS

Years of Analysis, N	Expected Fuel Inflation Rate					
	5%	8%	10%	15%	19% (Historical Rate)	25%
1	1.05	1.08	1.10	1.15	1.19	1.25
2	1.08	1.12	1.15	1.24	1.30	1.41
3	1.10	1.17	1.21	1.33	1.43	1.59
4	1.13	1.22	1.28	1.44	1.57	1.80
5	1.16	1.27	1.34	1.55	1.74	2.05
6	1.19	1.32	1.41	1.68	1.92	2.35
7	1.22	1.38	1.49	1.82	2.13	2.69
8	1.25	1.44	1.57	1.97	2.37	3.10
9	1.29	1.50	1.66	2.14	2.63	3.58
10	1.32	1.56	1.75	2.33	2.94	4.16

Note: Average Fuel Price (over N years) = Current Fuel Price x Fuel Price Adjustment Factor

APPENDIX: SAMPLE LIFE CYCLE COST ANALYSIS WORKSHEETS

SAMPLE WORKSHEET VI-1: FULL-SIZE VEHICLE

LIFE CYCLE COST DATA

REQUIRED INFORMATION		SOURCES
1. <input type="text" value="\$6200"/>	PURCHASE PRICE	DEALER: EQUIP. SUPPLIER
2. <input type="text" value="30000"/>	EXPECTED ANNUAL MILEAGE	DEPARTMENT HEADS
3. <input type="text" value="3 YRS"/>	NUMBER OF YEARS VEHICLE TO REMAIN IN FLEET	VEHICLE RECORDS
4. <input type="text" value="\$1000"/>	EXPECTED RESALE (SAL- VAGE) VALUE OF VEHICLE AT RETIREMENT	DEALER ESTIMATE DEPARTMENT HEADS VEHICLE RECORDS
5. <input type="text" value="5%"/>	DISCOUNT RATE	LOCAL POLICY
6. <input type="text" value="16mpg"/>	VEHICLE FUEL ECONOMY	EPA MILEAGE RATING(CITY)
7. <input type="text" value="\$1.00"/>	PRICE OF FUEL/GALLON	LOCAL FUEL DEALER
OPTIONAL INFORMATION		
8. <input type="text" value="\$1200"/>	EXPECTED ANNUAL MAINTENANCE COST	VEHICLE RECORDS
9. <input type="text" value="\$ 210"/>	ANNUAL INSURANCE COST	VEHICLE RECORDS
10. <input type="text" value="\$ 125"/>	OTHER ANNUAL COST	VEHICLE RECORDS

SAMPLE WORKSHEET VI-1: COMPACT VEHICLE

LIFE CYCLE COST DATA

REQUIRED INFORMATION		SOURCES
1. <input type="text" value="\$5000"/>	PURCHASE PRICE	DEALER: EQUIP. SUPPLIER
2. <input type="text" value="30000"/>	EXPECTED ANNUAL MILEAGE	DEPARTMENT HEADS
3. <input type="text" value="3 YRS"/>	NUMBER OF YEARS VEHICLE TO REMAIN IN FLEET	VEHICLE RECORDS
4. <input type="text" value="\$1250"/>	EXPECTED RESALE (SAL- VAGE) VALUE OF VEHICLE AT RETIREMENT	DEALER ESTIMATE DEPARTMENT HEADS VEHICLE RECORDS
5. <input type="text" value="5%"/>	DISCOUNT RATE	LOCAL POLICY
6. <input type="text" value="22mpg"/>	VEHICLE FUEL ECONOMY	EPA MILEAGE RATING(CITY)
7. <input type="text" value="\$1.00"/>	PRICE OF FUEL/GALLON	LOCAL FUEL DEALER
OPTIONAL INFORMATION		
8. <input type="text" value="\$1020"/>	EXPECTED ANNUAL MAINTENANCE COST	VEHICLE RECORDS
9. <input type="text" value="\$180"/>	ANNUAL INSURANCE COST	VEHICLE RECORDS
10. <input type="text" value="\$100"/>	OTHER ANNUAL COST	VEHICLE RECORDS

SAMPLE WORKSHEET VI-2: FULL-SIZE VEHICLE
ANNUAL OPERATING COSTS

1. ENTER the expected annual mileage (line 2, Worksheet VI-1)
2. ENTER the price of fuel per gallon (line 7, Worksheet VI-1)
3. MULTIPLY and enter the result
4. ENTER the fuel economy of the vehicle in miles per gallon (line 6, Worksheet VI-1)
5. DIVIDE the result in line 3 by the fuel economy in line 4 and enter the result
6. ENTER the annual maintenance cost (line 8, Worksheet VI-1)
7. ENTER the annual insurance cost (line 9, Worksheet VI-1)
8. ENTER miscellaneous annual costs (line 10, Worksheet VI-1)
9. ADD the costs of lines 5-8 and enter the result

30,000
 x \$1.00
 \$ 30,000
16 mpg

\$1875
ANNUAL FUEL COST
\$1200
\$ 210
\$ 125

\$3410
**ANNUAL
 OPERATING COST**

SAMPLE WORKSHEET VI-2: COMPACT VEHICLE
ANNUAL OPERATING COSTS

1. ENTER the expected annual mileage (line 2, Worksheet VI-1)
2. ENTER the price of fuel per gallon (line 7, Worksheet VI-1)
3. MULTIPLY and enter the result
4. ENTER the fuel economy of the vehicle in miles per gallon (line 6, Worksheet VI-1)
5. DIVIDE the result in line 3 by the fuel economy in line 4 and enter the result
6. ENTER the annual maintenance cost (line 8, Worksheet VI-1)
7. ENTER the annual insurance cost (line 9, Worksheet VI-1)
8. ENTER miscellaneous annual costs (line 10, Worksheet VI-1)
9. ADD the costs of lines 5-8 and enter the result

30000
 x \$1.00
 \$ 30,000
22 mpg

\$1364
ANNUAL FUEL COST
\$1020
\$ 180
\$ 100

\$2664
**ANNUAL
 OPERATING COST**

SAMPLE WORKSHEET VI-3: FULL SIZE VEHICLE

PRESENT WORTH OF FUTURE OPERATING COSTS AND SALVAGE VALUE

1. ENTER the number of years the vehicle is to remain in the fleet (line 3, Worksheet VI-1) 3 YRS
 2. ENTER the acceptable discount rate (line 5, Worksheet VI-1) 5%
 3. SELECT an operating cost discount factor in Table A using the values specified in lines 1 and 2
 4. ENTER the appropriate discount factor from Table A 2.723
 5. ENTER the annual operating cost (line 9, Worksheet VI-2) x \$3410
 6. MULTIPLY lines 4 and 5 and enter the result \$9285 TOTAL OPERATING COST
-
7. SELECT a salvage value discount factor in Table B using the values specified in lines 1 and 2
 8. ENTER the appropriate salvage value discount factor from Table B 0.8638
 9. ENTER the resale value of the vehicle (line 4, Worksheet VI-1) x \$1,000
 10. MULTIPLY lines 8 and 9 and enter the result \$864 DISCOUNTED SALVAGE VALUE
 11. SUBTRACT the discounted salvage value (line 10) from the total operating cost (line 6) and enter the result \$8421 NET VEHICLE OPERATING COST

TABLE A
DISCOUNT RATE

YR	3%	4%	5%	8%	10%
1	0.971	0.962	0.952	0.926	0.909
2	1.913	1.866	1.859	1.783	1.736
3	2.829	2.755	2.723	2.577	2.487
4	3.717	3.630	3.546	3.312	3.170
5	4.580	4.452	4.329	4.623	3.791
6	5.417	5.242	5.076	5.206	4.355
7	6.230	6.002	5.786	5.747	4.868

TABLE B
DISCOUNT RATE

YR	3%	4%	5%	8%	10%
1	.9709	.9615	.9524	.9259	.9091
2	.9426	.9246	.9570	.8573	.8264
3	.9151	.8890	.8638	.7938	.7513
4	.8885	.8548	.8227	.6806	.6830
5	.8626	.8219	.7835	.6302	.6209
6	.8375	.7903	.7462	.5835	.5645
7	.8131	.7599	.7107	.5403	.5131

SAMPLE WORKSHEET VI-3: COMPACT VEHICLE

PRESENT WORTH OF FUTURE OPERATING COSTS AND SALVAGE VALUE

1. ENTER the number of years the vehicle is to remain in the fleet (line 3, Worksheet VI-1) 3 YRS
2. ENTER the acceptable discount rate (line 5, Worksheet VI-1) 5%
3. SELECT an operating cost discount factor in Table A using the values specified in lines 1 and 2
4. ENTER the appropriate discount factor from Table A 2.723
5. ENTER the annual operating cost (line 9, Worksheet VI-2) x \$2664
6. MULTIPLY lines 4 and 5 and enter the result \$7254 TOTAL OPERATING COST

TABLE A
DISCOUNT RATE

YR	3%	4%	5%	8%	10%
1	0.971	0.962	0.952	0.926	0.909
2	1.913	1.866	1.859	1.783	1.706
3	2.829	2.755	2.723	2.577	2.487
4	3.717	3.630	3.546	3.312	3.170
5	4.580	4.452	4.329	4.023	3.791
6	5.417	5.242	5.076	4.706	4.355
7	6.230	6.002	5.786	5.347	4.868

7. SELECT a salvage value discount factor in Table B using the values specified in lines 1 and 2
8. ENTER the appropriate salvage value discount factor from Table B 0.8638
9. ENTER the resale value of the vehicle (line 4, Worksheet VI-1) x \$1250
10. MULTIPLY lines 8 and 9 and enter the result \$1080 DISCOUNTED SALVAGE VALUE
11. SUBTRACT the discounted salvage value (line 10) from the total operating cost (line 6) and enter the result \$6174 NET VEHICLE OPERATING COST

TABLE B
DISCOUNT RATE

YR	3%	4%	5%	8%	10%
1	.9709	.9615	.9524	.9259	.9091
2	.9426	.9246	.9170	.8573	.8264
3	.9151	.8890	.8638	.7938	.7513
4	.8885	.8548	.8227	.6806	.6330
5	.8626	.8219	.7835	.6302	.5809
6	.8375	.7903	.7462	.5835	.5345
7	.8131	.7599	.7107	.5403	.5131

SAMPLE WORKSHEET VI-4: FULL-SIZE VEHICLE

COMPUTE LIFE CYCLE COST

1. ENTER the purchase price of the vehicle
(line 1, Worksheet VI-3)

\$6,200

2. ENTER the net vehicle operating cost
(line 11, Worksheet VI-3)

\$8421

3. ADD lines 1 and 2 and enter the result

\$14621

LIFE
CYCLE
COST

(OPTIONAL)

4. ENTER the number of years vehicle is to
remain in fleet, YRS

3 YRS

5. DIVIDE line 3 by line 4 and ENTER the
result

\$4874

AVERAGE ANNUAL
LIFE CYCLE COST

SAMPLE WORKSHEET VI-4: COMPACT VEHICLE

COMPUTE LIFE CYCLE COST

1. ENTER the purchase price of the vehicle
(line 1, Worksheet VI-1)

\$ 5,000

2. ENTER the net vehicle operating cost
(line 11, Worksheet VI-1)

\$ 6,174

3. ADD lines 1 and 2 and enter the result

\$11,174

LIFE
CYCLE
COST

(OPTIONAL)

4. ENTER the number of years vehicle is to
remain in the fleet, YRS

3 YRS

5. DIVIDE line 3 by line 4 and ENTER the
result

\$ 3,725.

AVERAGE ANNUAL
LIFE CYCLE COST

WORKSHEET A-1

LIFE CYCLE COST DATA

REQUIRED INFORMATION		SOURCES
1. \$ <input type="text"/>	PURCHASE PRICE	DEALER: EQUIPMENT SUPPLIER
2. <input type="text"/> MI	EXPECTED ANNUAL MILEAGE	DEPARTMENT HEADS
3. <input type="text"/> YRS	NUMBER OF YEARS VEHICLE TO REMAIN IN FLEET	VEHICLE RECORDS
4. \$ <input type="text"/>	EXPECTED RESALE (SALVAGE) VALUE OF VEHICLE AT RETIREMENT	DEALER ESTIMATE DEPARTMENT HEADS VEHICLE RECORDS
5. <input type="text"/> %	DISCOUNT RATE	LOCAL POLICY
6. <input type="text"/> MPG	VEHICLE FUEL ECONOMY	EPA MILEAGE RATING (CITY)
7. \$ <input type="text"/>	PRICE OF FUEL PER GALLON	LOCAL FUEL DEALER
OPTIONAL INFORMATION		
8. \$ <input type="text"/>	EXPECTED ANNUAL MAINTENANCE COST	VEHICLE RECORDS
9. \$ <input type="text"/>	ANNUAL INSURANCE COST	VEHICLE RECORDS
10. \$ <input type="text"/>	OTHER ANNUAL COST	VEHICLE RECORDS

WORKSHEET A-2

ANNUAL OPERATING COSTS

1. ENTER THE EXPECTED ANNUAL MILEAGE (LINE 2, WORKSHEET VI-1)
2. ENTER THE PRICE OF FUEL PER GALLON (LINE 7, WORKSHEET VI-1)
3. MULTIPLY AND ENTER THE RESULT
4. ENTER THE FUEL ECONOMY OF THE VEHICLE IN MILES PER GALLON (LINE 6, WORKSHEET VI-1)
5. DIVIDE THE RESULT IN LINE 3 BY THE FUEL ECONOMY IN LINE 4 AND ENTER THE RESULT
6. ENTER THE ANNUAL MAINTENANCE COST (LINE 8, WORKSHEET VI-1)
7. ENTER THE ANNUAL INSURANCE COST (LINE 9, WORKSHEET VI-1)
8. ENTER THE MISCELLANEOUS ANNUAL COSTS (LINE 10, WORKSHEET VI-1)
9. ADD THE COSTS OF LINES 5-8 AND ENTER THE RESULT

 MBX \$ MPG

<input type="text"/> \$
ANNUAL FUEL COST
<input type="text"/> \$
<input type="text"/> \$
<input type="text"/> \$

 \$

ANNUAL
OPERATING COST

WORKSHEET A-3

PRESENT WORTH OF FUTURE OPERATING COSTS AND SALVAGE VALUE

1. ENTER the number of years the vehicle is to remain in the fleet (line 3, Worksheet VI-1)
 2. ENTER the acceptable discount rate (line 5, Worksheet VI-1)
 3. SELECT an operating cost discount factor in Table A using the values specified in lines 1 and 2.
 4. ENTER the appropriate discount factor from Table A
 5. ENTER the annual operating cost (line 9, Worksheet VI-2) x \$
 6. MULTIPLY lines 4 and 5 and enter the result
\$ TOTAL OPERATING COST
-
7. SELECT a salvage value discount factor in Table B using the values specified in lines 1 and 2
 8. ENTER the appropriate salvage value discount factor from Table B
 9. ENTER the resale value of the vehicle (line 4, Worksheet VI-1) x \$
 10. MULTIPLY lines 8 and 9 and enter the result
\$ DISCOUNTED SALVAGE VALUE
 11. SUBTRACT the discounted salvage value (line 10) from the total operating cost (line 6) and enter the result \$ NET VEHICLE OPERATING COST

TABLE A
DISCOUNT RATE

YR	3%	4%	5%	8%	10%
1	0.971	0.962	0.952	0.926	0.909
2	1.913	1.866	1.859	1.783	1.736
3	2.829	2.755	2.723	2.577	2.487
4	3.717	3.630	3.546	3.312	3.170
5	4.580	4.452	4.329	4.623	3.791
6	5.417	5.242	5.076	5.206	4.355
7	6.230	6.002	5.786	5.747	4.868

TABLE B
DISCOUNT RATE

YR	3%	4%	5%	8%	10%
1	.9709	.9615	.9524	.9259	.9091
2	.9426	.9246	.9570	.8573	.8264
3	.9151	.8890	.8638	.7938	.7513
4	.8885	.8548	.8227	.6806	.6830
5	.8626	.8219	.7835	.6302	.6209
6	.8375	.7903	.7462	.5835	.5645
7	.8131	.7599	.7107	.5403	.5131

WORKSHEET A-4

COMPUTE LIFE CYCLE COST

1. ENTER THE PURCHASE PRICE OF THE VEHICLE
(LINE 1, WORKSHEET VI-1)

\$

2. ENTER THE NET VEHICLE OPERATING COST
(LINE 11, WORKSHEET VI-3)

\$

3. ADD LINES 1 AND 2 AND ENTER THE RESULT

\$

LIFE
CYCLE
COST

(OPTIONAL)

4. ENTER THE NUMBER OF YEARS VEHICLE IS TO
REMAIN IN FLEET YRS

YRS

5. DIVIDE LINE 3 AND LINE 5 AND ENTER THE
RESULT

\$

AVERAGE ANNUAL
LIFE CYCLE COST