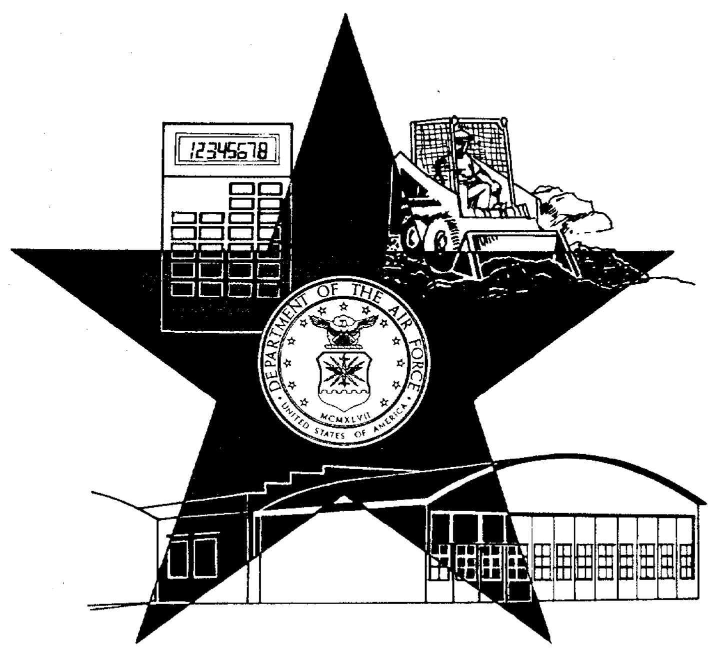
ornl

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

ORNL/TM-10476/V1

Military Construction Program Economic Analysis Manual: Text and Appendixes



OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A07 Microfiche A01

ORNL/TM-10476/V1

MILITARY CONSTRUCTION PROGRAM ECONOMIC ANALYSIS MANUAL: TEXT AND APPENDIXES

Hazardous Waste Remedial Actions Program

Date Published: December 1987

Prepared for:
THE UNITED STATES AIR FORCE

SAF/ACC and USAF/LEE coordinated document

Prepared by:
URS CORPORATION
Santa Barbara, California 93101

and

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

MILITARY CONSTRUCTION PROGRAM
ECONOMIC ANALYSIS MANUAL

Contents

Page

Volume 1. Text and Appendixes

Abstract vii
Introduction 1
Determining Whether to Perform an Economic Analysis 5
How to Use this Manual 7
Step 1: Defining the Requirement 11
Step 2: Identifying Alternatives 15
Step 3: Calculating Life-Cycle Costs 21
Step 4: Evaluating Benefits 37
Step 5: Comparing Costs and Benefits of Alternatives 47
Step 6: Performing Sensitivity Analyses 55
Step 7: Documenting the Analysis 59

Appendixes
- Appendix A: Glossary A-1
- Appendix B: Life-Cycle Cost Data Sources B-1
- Appendix C: Economic Analysis Multipliers C-1
- Appendix D: Qualitative Evaluation Criteria D-1

Volume 2. Sample Economic Analyses

Preface 1
Unaccompanied Enlisted Personnel Housing S1-1
Consolidated Supply Facility S2-1
Air Test Center Engineering Management Facility S3-1

List of Figures

Page

Figure 1: Economic Analysis Flow Diagram 8

Figure 2: Cash Flow Diagram 49

MILITARY CONSTRUCTION PROGRAM ECONOMIC ANALYSIS MANUAL: TEXT AND APPENDIXES

ABSTRACT

The purpose of this manual is to enable the U.S. Air Force to comprehensively and systematically analyze alternative approaches to meeting its military construction requirements. The manual includes step-by-step procedures for completing economic analyses for military construction projects, beginning with determining if an analysis is necessary. Instructions and a checklist of the tasks involved for each step are provided; and, when appropriate, examples of calculations and illustrations of completed forms are included. The manual explains the major tasks of an economic analysis, including (1) identifying the problem, (2) selecting realistic alternatives for solving it, (3) formulating appropriate assumptions, (4) determining the costs and benefits of the alternatives, (5) comparing the alternatives, (6) testing the sensitivity of major uncertainties, and (7) ranking the alternatives. Appendixes are included that contain data, indexes, and worksheets to aid in performing the economic analyses. For reference, Volume 2 contains sample economic analyses that illustrate how each form is filled out and that include a complete example of the documentation required.

INTRODUCTION

The purpose of the *Military Construction Program Economic Analysis Manual* is to enable the Air Force to comprehensively and systematically analyze alternative approaches to meeting its military construction requirements. According to *Defense Economic Issues*,[1] the basic purpose of using economic analysis "is to improve decision making generally." The publication also states:

> Economic analysis settles on providing information about cost/benefit relationships as a basis for optimizing the use of scarce resources. Economic analysis in the Department of Defense thus provides the structure and information base upon which program accomplishments can be measured and evaluated. Consequently, increased productivity and efficiency are made more likely with the aid of economic analysis.

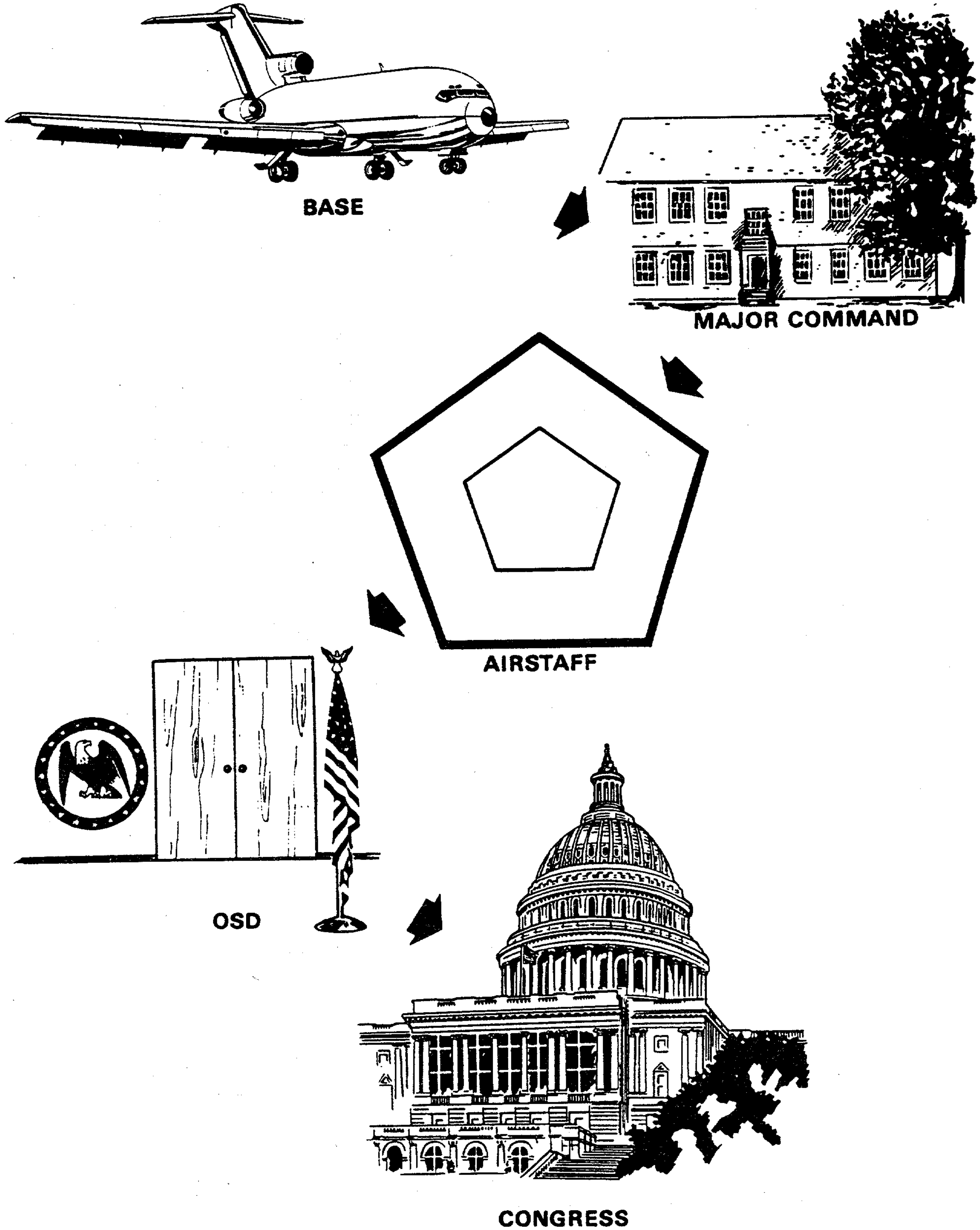
Economic scarcity requires that choices be made in the use of resources, and economic analysis is one process by which such choices can be made. It ensures that feasible alternatives are evaluated in a thorough, consistent, and objective manner. A complete economic analysis should be one of the factors contributing to a proper decision on the use of resources. However, it is not the decision-making process itself; as stated in *Defense Economic Issues*:

> The intended purpose of the economic analysis is not to dictate the decision, but rather to represent an instrument that brings to the attention of the decisionmaker the possible economic trade-offs and opportunity costs associated with various courses of action. Economic considerations, however important, are only one of a set of considerations that decisionmakers must take into account while coming to a decision.

Not all economic analyses require the same level of effort. The extent of analysis should be commensurate with the complexity of the action proposed, the issues involved, and the magnitude of resources. Although the analysis may involve only an hour's research, it may nonetheless provide the basis for a more informed decision. An essential element of economic analysis is cost analysis, because costs constitute one side of every economic analysis equation, regardless of the type of study (e.g., cost-benefit analysis, decision analysis, or alternatives analysis). The quality of an economic analysis also depends on the adequacy of the alternatives evaluated.

---

1. National Security Management Series, National Defense University, Washington, D.C., 1982.


BASE
MAJOR COMMAND
AIRSTAFF
OSD
CONGRESS

The most important step in economic analysis is to identify all reasonable ways to satisfy the objective. Since the purpose of the analysis is to help the decision maker allocate resources efficiently, care must be taken to identify all reasonable alternatives that could meet the objectives. The recommendation resulting from the economic analysis will come from among those alternatives. In considering alternatives, one must recognize that continuing the present course of action may be a feasible alternative. In addition, all alternatives need not be considered to the same degree. When a candidate alternative is eliminated from consideration, specific reasons for dropping that alternative are documented in the analysis.

Life-cycle costs, which include all construction, operations, and maintenance costs over the life of a facility, are used as the common denominator for comparing the relative costs of possible alternatives. Although cost is a major consideration in selecting the best alternative, it is not the only one. Project costs must be weighed against the benefits the project provides, so that the relative strengths and weaknesses of competing alternatives can be brought into clearer focus. Economic analysis is a tool used to compare the financial consequences of two or more alternatives. It also serves as evidence to reviewers that all the economic factors bearing on the recommended decision have been considered.

It is imperative that an economic analysis be accomplished as early in project planning and development as possible. An early start allows a superior life cycle cost model to be developed, provides better information for early program decision making, and lays the foundation for superior program support documentation. For planning and programming purposes, an evaluation of reasonable alternatives should be considered during the project concept phase.

The initial program submittal to Air Staff (HQ USAF/LEEP) should indicate for which military construction program (MCP) projects an economic analysis is being or has been accomplished. The completed analysis must be included in the final MCP program submittal. It is recommended that each economic analysis be reverified based on 35% design costs estimates and that a revised analysis be submitted if updated estimates result in a change in project scope or recommended alternative.

The comptroller organization (AC) has primary responsibility for economic analyses, including data collection, problem analysis, and documentation. AC will also assume primary responsibility for certification. Engineering (DE) has primary responsibility for initiating the economic analysis, developing the alternatives considered in the analysis, drawing conclusions and making recommendations, and forwarding the documentation through the proper channels to meet program deadlines.

Completing the analysis requires close coordination among AC, DE, and the ultimate user of the facility. Most tasks involve shared responsibility, and effective economic analysis requires a cooperative team effort. The table below shows the organizations that have primary and collateral responsibilities for each of the major tasks in an economic analysis.

	Organization		
Task	*AC*	*DE*	*User*
Initiating an Economic Analysis		primary	
Developing Alternatives		primary	collateral
Data Collection	primary	collateral	collateral
Data Analysis	primary		
Drawing Conclusions	collateral	primary	collateral
Making Recommendations	collateral	primary	collateral
Documentation	primary		
Certification	primary	collateral	

If an economic analysis is performed for a project, the written results are forwarded with the project's DD Form 1391 documentation through the budget review process. After it is prepared at the base level, the analysis is reviewed by the major command, forwarded to air staff (LEEP), and furnished to the Office of the Secretary of Defense (OSD) with the Budget Estimate Submission (BES). It is submitted to Congress on request.

DETERMINING WHETHER TO PERFORM AN ECONOMIC ANALYSIS

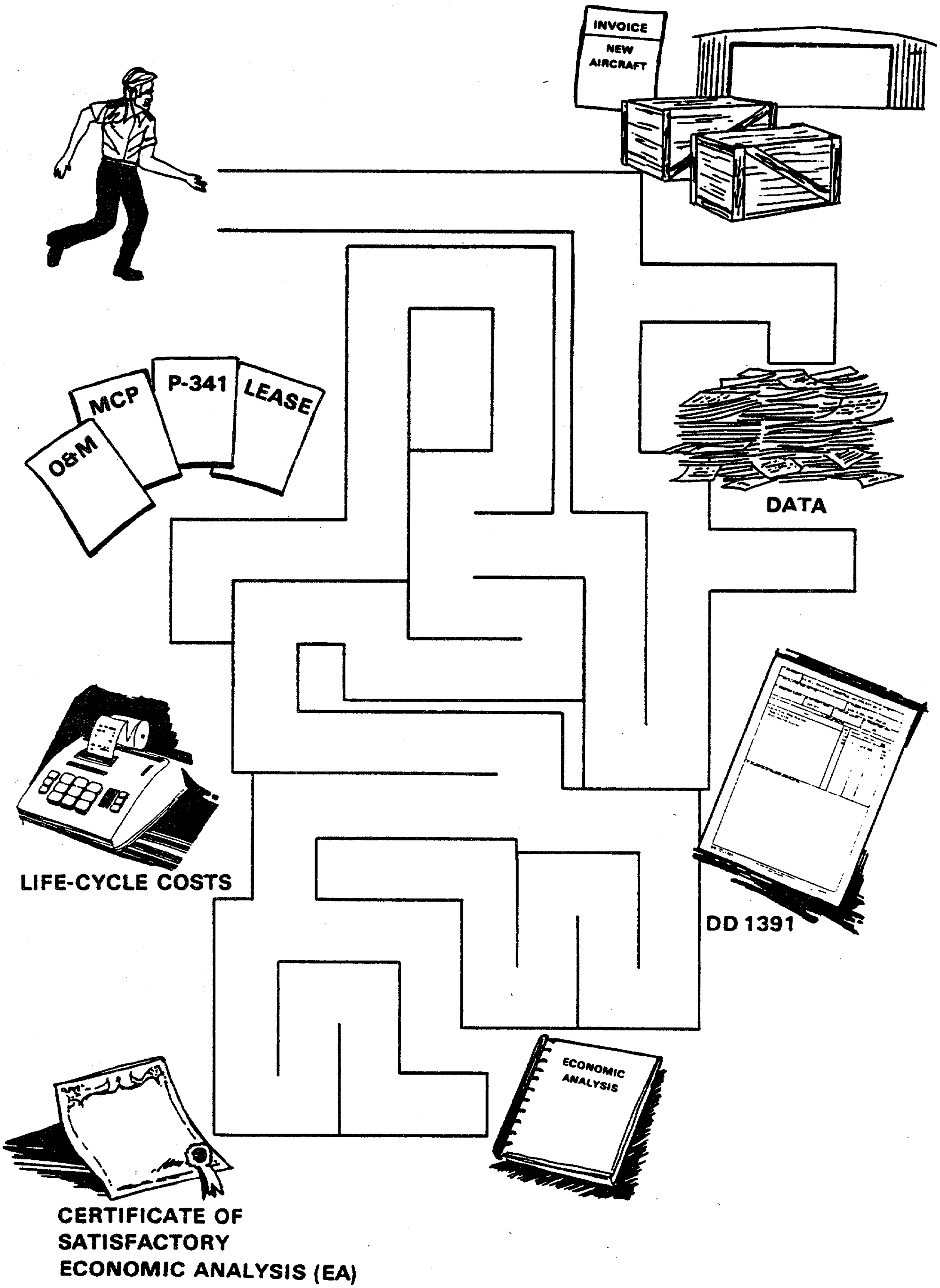
An economic analysis is recommended whenever the potential exists for cost savings or other benefits. As specified in AFR 178-1, "a program is evaluated only if the benefits of the evaluation clearly outweigh the cost of collecting the data and conducting the evaluation."

The Engineering and Services staff at major command level will determine when an economic analysis is required for MCP projects, based on the following guidelines:

1. Whenever the principal justification for a project is economic (i.e., the main purpose of the project is to reduce costs), an economic analysis should be included with the DD Form 1391, Military Construction Program Data, indicating the alternatives considered and providing an analysis of those alternatives.

2. In virtually every case, an economic analysis is also necessary for project approval by OSD and Congress when one or more of the following conditions prevails: (a) anticipated investment costs for a project exceed 50% of replacement (build new) costs; (b) the project improves organizational or operational efficiency, including consolidation of like organizations into a single facility; (c) anticipated project investment costs exceed $10 million; (d) the project includes disposal or major revitalization of a large number of facilities that are energy inefficient or require excessive maintenance and repair; and/or (e) the project is a realistic candidate for alternative financing.

3. An economic analysis should not be necessary if any of the following conditions apply: (a) project investment costs are less than $1 million; (b) project investment costs are less than $2 million and do not exceed 50% of replacement costs (this does not apply to consolidation projects); (c) the project corrects problems or violations involving health, safety, fire protection, pollution, or security; (d) the project is directed by statute, regulation, or higher authority than DOD, and the provisions of such direction preclude choices among alternatives to meet the requirement (this exemption does not apply if the proposed project is the result of an Air Force request approved by Congress; a clear and concise justification for the exemption to the analysis must be given in Block 11 of DD Form 1391); or (e) there is only a single way to meet a valid requirement (this would be a rare case, because any alternative meeting the minimum requirements, including maintenance of the status quo, is feasible if it cannot be excluded on noneconomic grounds).


INVOICE
NEW AIRCRAFT
MCP
P-341
LEASE
O&M
DATA
LIFE-CYCLE COSTS
DD 1391
ECONOMIC ANALYSIS
CERTIFICATE OF
SATISFACTORY
ECONOMIC ANALYSIS (EA)

HOW TO USE THIS MANUAL

The major tasks of an economic analysis are to identify the problem, select realistic alternatives for solving it, formulate appropriate assumptions, determine the costs and benefits of the alternatives, compare the alternatives, test the sensitivity of major uncertainties, and rank the alternatives. Figure 1 is a flow diagram of the economic analysis process.

This manual can be used by personnel at individual bases, major commands, or headquarters. It includes (in Vol. I)

1. step-by-step procedures for completing an economic analysis for military construction projects;

2. the following appendices to assist in performing an economic analysis: (a) Appendix A: Glossary; (b) Appendix B: Life-Cycle Cost Data Sources, which includes default values that can be used if local data are unavailable; (c) Appendix C: Economic Analysis Multipliers, which includes OSD inflation indexes and multipliers for discounting future costs; (d) Appendix D: Qualitative Evaluation Criteria for the benefits portion of the analysis; (e) Appendix E: Worksheets and Forms for calculating life-cycle costs and benefits; and (in Vol. II)

3. sample economic analyses (under separate cover).

The first part of this manual contains the step-by-step procedures for completing the economic analysis; the process consists of seven steps, which are described in the following sections. Each section provides instructions and, when appropriate, includes examples of calculations and illustrations of completed forms.

Also included is a checklist of the tasks involved in each step. Once you have become familiar with the procedures, you may be able to perform economic analyses using only the checklists as a guide. For further clarification, refer to the sample economic analyses, which illustrate how each form is filled out and include a complete example of the documentation required.

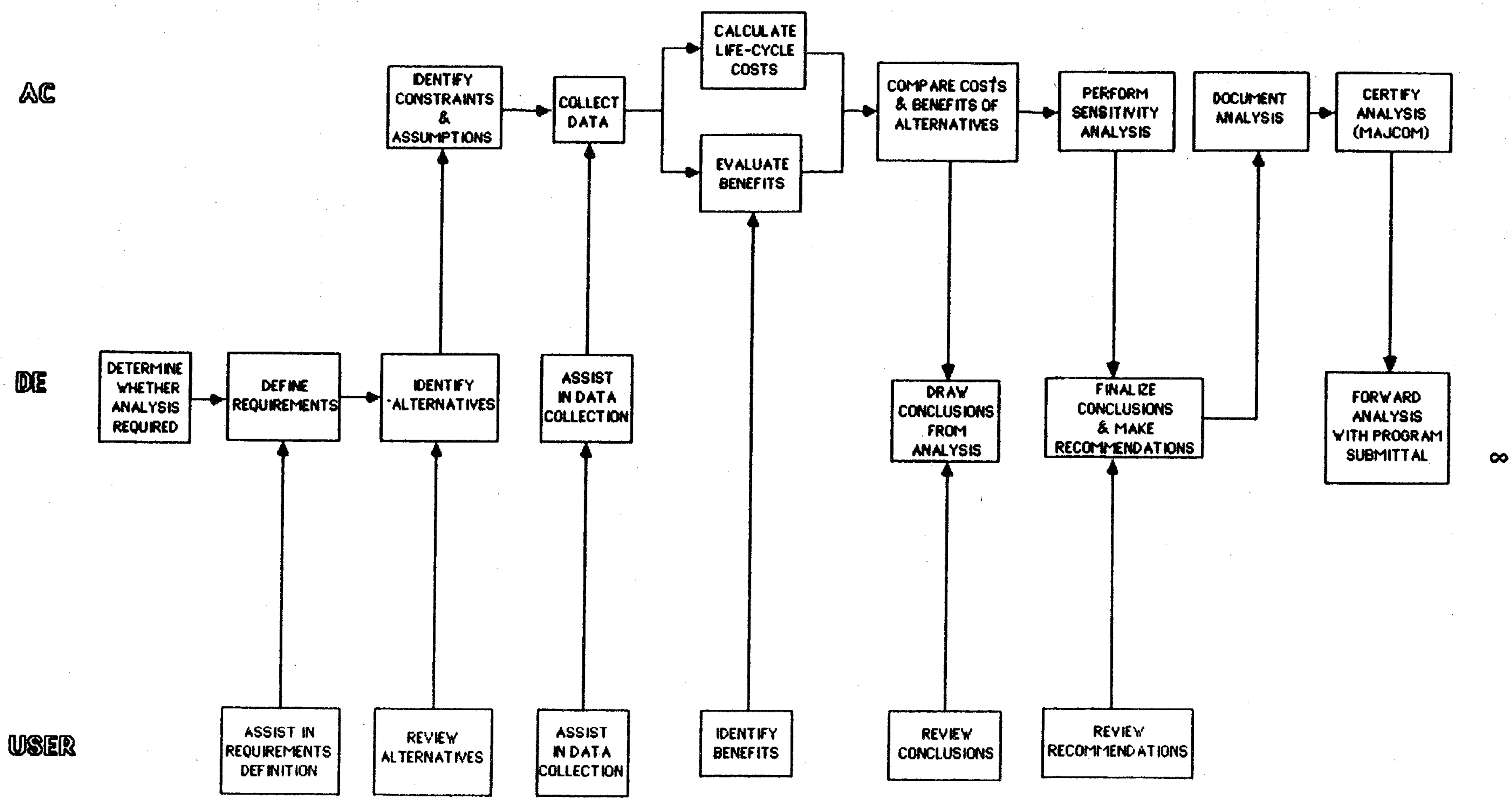
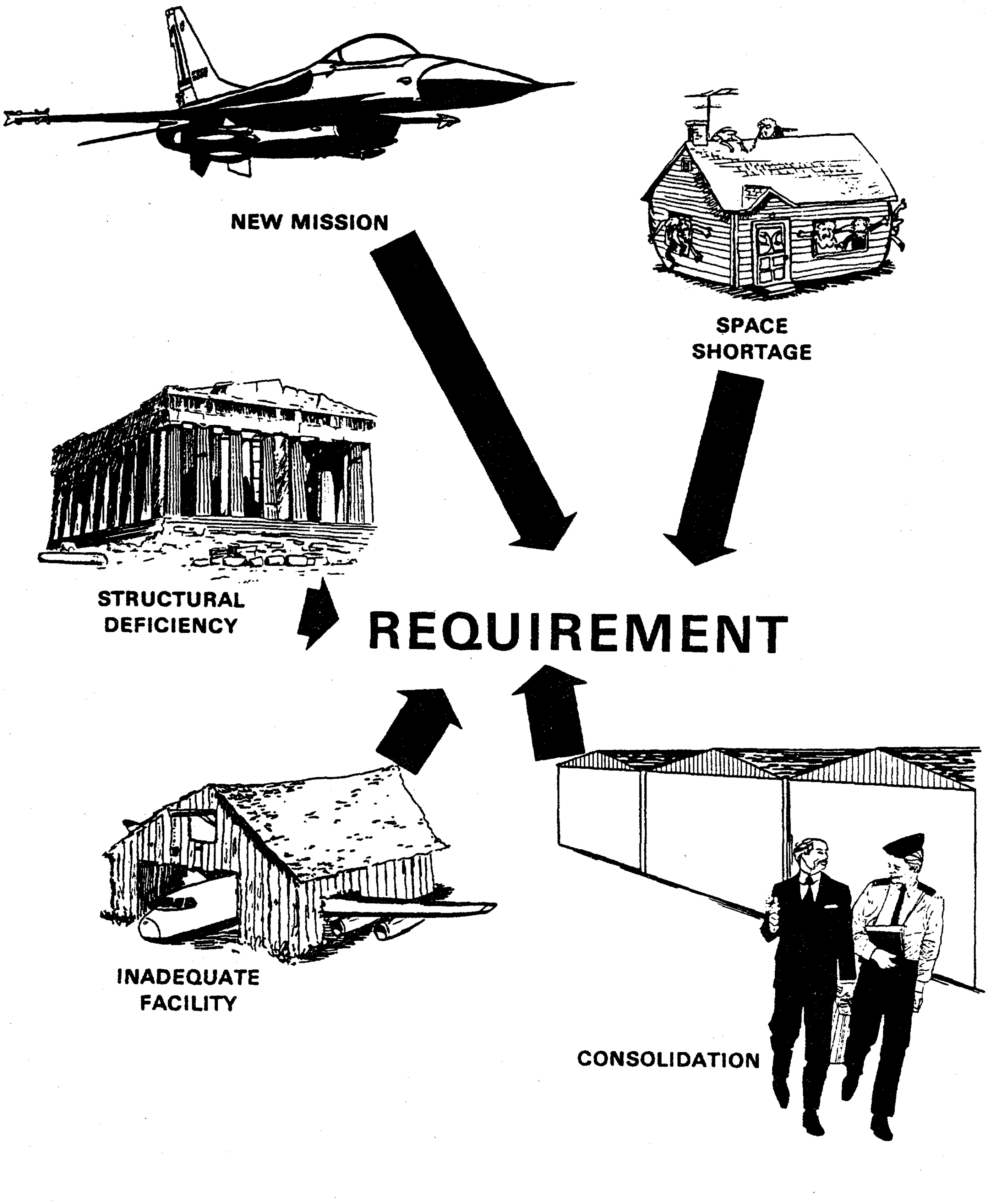


Figure 1

ECONOMIC ANALYSIS FLOW DIAGRAM

Following the steps in this manual will lead to a complete economic analysis. A detailed analysis may not always be required, however. In that case, any of the procedures outlined in the manual (e.g., identifying alternatives) that assist in focusing the issues for better decision making can be used on an informal basis.


NEW MISSION
SPACE
SHORTAGE
STRUCTURAL
DEFICIENCY
REQUIREMENT
INADEQUATE
FACILITY
CONSOLIDATION

STEP 1: DEFINING THE REQUIREMENT

The first step in the economic analysis process is to define the nature and scope of the requirement. A clear definition of need is essential in determining what the base's requirements are and evaluating how well various approaches meet those requirements:

> With economic analysis focused on providing relevant information that will enable management to make wise and pertinent decisions, it becomes critical for analysts to have a clear conception of what the problem really is. (*Defense Economic Issues)*

A clear definition of the problem is the basis for identifying and evaluating alternatives. Determining which alternatives are feasible for a particular project requires knowing precisely what the needs are. The criteria for measuring the benefits of alternatives also depend on the project objectives to satisfy specific requirements.

A project may be proposed to correct one or more of the following deficiencies:

1. a new functional requirement resulting from a new mission or mission change;
2. a space shortage;
3. an engineering deficiency;
4. a health, safety, fire protection, or security problem;
5. excessive operations and maintenance (O&M) costs;
6. functional inadequacy, including facilities that do not meet the standards specified in *Air Force Manual (AFM) 86-2*; or
7. an inefficient condition, including inefficient use of energy or space.

Often a project identified to meet one requirement may be expanded to meet others. For instance, a facility addition designed to correct a space shortage may also correct structural deficiencies or increase energy conservation. Therefore, when defining a requirement for programming, it is important to look for all potential deficiencies to ensure that the proposed project results in an adequate, usable facility.

The checklist for this section can be used to establish the number and type of deficiencies requiring correction in existing base facilities. It is only a guide to determining what areas need correction and is not intended as a comprehensive list of possible deficiencies; other problems may exist. You should consider using the concerns of current facility users as a data source for identifying deficiencies.

CHECKLIST

STEP 1: DEFINING THE REQUIREMENT

Check applicable deficiencies:

- Mission expansion or change ☐
- Space shortage/inadequacy ☐
- Inefficient layout/space utilization ☐
- Structural deficiency ☐
- Health violation ☐
- Safety violation ☐
- Fire protection ☐
- Security requirement ☐
- Utilities deficiency ☐
- Inefficient energy use ☐
- Other (specify)

  ______________________________ ☐

STEP 2: IDENTIFYING ALTERNATIVES

By definition, the approach selected to meet a need will be one of the alternatives considered. Therefore, it is critical that in the decision-making process a range of alternatives is examined to determine which alternatives are reasonable so that they can be evaluated to find the best one. For an alternative to be considered reasonable, it should be consistent with Air Force regulations and legal requirements. Adequacy and economic feasibility are other key considerations in the identification of reasonable alternatives. Adequacy refers to the capacity of the potential alternative to meet the actual scope or objective. For a potential alternative to be economically feasible, it must be compatible with funding realities.

Alternatives analysis is an iterative process. The first step is a quick and simple examination of the range of potential alternatives to determine which are reasonable and should be evaluated in detail. The checklist at the end of this section includes a list of types of alternatives and provides space for a brief explanation for any determined to be unreasonable. This information should be summarized in the economic analysis documentation (Step 7). An alternative that meets the requirements, including the status quo, is feasible if it cannot be eliminated on noneconomic grounds.

It is possible that only one alternative will be reasonable. In that case, an economic analysis is normally not required. More often, there are two or three reasonable alternatives that warrant serious evaluation. Normally, no more than four or five alternatives are considered in detail, although there are exceptions.

An alternative can be eliminated from further consideration in the analysis whenever it appears to no longer adequately meet the need. The economic analysis itself should be pursued only as long as it is useful to the decision-making process. It can be completed and the findings documented at any stage. For example, you may have considered a number of alternatives, but as the analysis progresses, only two emerge as feasible. The preliminary calculation of life-cycle costs and benefits demonstrates that one of the two alternatives is clearly superior to or less costly than the other. At that point, there is no benefit to be gained from completing a rigorous analysis. Your findings should simply be documented in a short report or memorandum.

Accurately defining the alternatives is also critical. Sometimes the best solution is not the most obvious one, and some innovative thought is required to come up with possible approaches to a problem. In defining alternatives, take a comprehensive view and include considerations related to the alternative but outside the "five-foot line." For instance, if an alternative involves constructing a new facility, you should consider what will happen to the existing facility. If the new facility is a replacement facility to be located at a different site, some thought should be given to how to use the old site. Conversely, if the replacement facility is to be constructed at the same site as the existing facility, the analysis must take into account how the using function will be accommodated during construction. These are just some examples of what a thorough analysis of the alternatives entails.

Remember, too, that improved facilities are just one way to meet a need. Other alternatives may include making operations more efficient so that new facilities are not required. For instance, a shortage of warehouse space may be compensated for by acquiring new handling and stacking equipment that allows more efficient use of vertical space (i.e., cubed footage). Another solution may involve consolidating related functions to make better use of existing or new space. These innovative approaches to meeting space needs can result in significant cost savings as well as improve operational efficiency and/or productivity.

For this manual, potential alternatives have been grouped into five primary types. These should be defined and tailored according to your specific needs. The documentation you prepare should indicate how each alternative you evaluated was defined to meet a specific requirement.

The types of alternatives are described below in general terms, with some suggestions for more specific variations. These should not be considered exhaustive; you are encouraged to think of other variations that may be appropriate to your specific circumstances. *It is important to note that your economic analysis may involve more than one alternative within each type.* For instance, you may want to consider an alternative that involves new construction and demolishing the existing facility and another alternative that involves new construction and converting the existing facility to another use. Both are grouped below under the "new construction" alternative. *It is also important to note that specific alternatives may involve a combination of types.* For instance, a change in operations may be combined with modification of an existing facility. The primary type of alternatives are:

1. CONTINUATION OF CURRENT CONDITIONS (STATUS QUO). The status quo assumes that existing facilities will continue to be used and that routine maintenance will continue to be performed. In addition to being an alternative, it also normally constitutes the baseline against which all other alternatives are evaluated. If you are considering a project, it is probably because you have an existing deficiency. The alternatives you consider for meeting the deficiency will be evaluated based on how much better they are than your current condition. Thus, you are actually comparing all alternatives to the status quo.

The status quo may not always be a feasible alternative, especially if there is a new mission requirement. Nevertheless, the costs of current operations may need to be included in the economic analysis to calculate benefits, some of which are measured in terms of incremental improvements over the status quo (see Step 4).

2. NEW CONSTRUCTION. A new on-base facility may be required to eliminate an existing shortage or deficiency, to meet a shortage or deficiency created by a new mission or mission change, or to replace a substandard facility. If new construction involves replacing an existing facility, the analysis must address the disposition of the existing facility. Variations of the new construction alternative include: (a) new construction that does not replace an existing facility; (b) construction of a replacement facility on the same site as an existing facility and demolition of the old facility; (c) construction of a replacement facility on a different site and demolishing or closing up the existing facility; and (d) construction of a replacement facility on a different site and converting the existing facility to another use.

3. MODIFICATION OF EXISTING FACILITY. This alternative may involve renovating an existing facility to eliminate deficiencies and/or reduce future maintenance and repair costs, altering the facility to improve its operating efficiency, or adding on to the facility to increase space. The actual work to be performed must be explicitly documented in the economic analysis.

4. LEASING OF OFF-BASE FACILITY. This alternative involves direct, long-term leasing or guaranteed rental by the Air Force of a suitable, privately owned facility off base. As with the new construction alternative, if leasing is used to replace an existing facility, the disposition of the existing facility must be included in the analysis.[2]

   Office of Management and Budget (OMB) Circular A-104 contains mandatory procedures for evaluating leasing as an alternative to new on-base construction. These procedures, among other things, stipulate the use of different discount rates in calculating life-cycle costs. If you are considering leasing as an alternative, you can use this manual to perform an initial analysis. If your analysis indicates that leasing and new construction are comparably viable alternatives, the procedures stipulated in the OMB circular must be used to complete the economic analysis.

---

2. **This alternative normally involves leasing existing facilities. A private developer could also construct a facility specifically to meet an Air Force requirement, and then lease the facility to the Air Force (build to lease). Private-sector development is sometimes an option for customer-related facilities on base, such as restaurants, VOQs, concessions, banks, and child-care centers. Some procedures for evaluating private-sector development differ from those presented in this manual.**

5. Change in Operations. This alternative involves a change in the status quo that does not include a change in facilities. It may be possible to improve a function's capability within its existing facility through a change in organization, operating procedure, or functional layout. This alternative might also involve acquiring new equipment that could be accommodated within the existing facility, for example, obtaining new supply-handling equipment to make more efficient use of existing warehouse space. Options for making more effective use of existing resources should be considered whenever a major investment in new resources is being contemplated.

DISPOSING OF EXISTING FACILITIES

Deciding what to do with an existing facility that is being replaced involves identifying, evaluating, and comparing options. The decision must then be documented in the economic analysis. Consider the following approaches for disposition of an existing facility, if one or more of the alternatives involves a replacement facility:

1. Converting the facility to another use. This is normally only an option if an existing need could be met by the conversion. Conversion costs are assumed to be borne by the new occupant and are not included in the economic analysis.

2. Demolishing the facility. This option should be considered whenever the existing facility is substandard, if its site is required for a new facility, or if there is no other potential use for it. Facilities are a resource, however, so before demolition is selected, consideration should be given to potential future use, even if there is no current need for the facility. The cost of demolition must be included in the life-cycle analysis.

3. Placing the facility in protective storage. This option involves closing up the facility and preserving it for potential future use by providing periodic maintenance to preserve its structural integrity; "mothballing" and "pickling" are colloquial terms for protective storage. This option should be considered whenever the existing facility is historic or when appropriate for other reasons. O&M costs for protective storage must be included in the life-cycle analysis.

CHECKLIST

STEP 2: IDENTIFYING ALTERNATIVES

	Infeasible	Feasible
Maintain status quo	☐	☐
If infeasible, explain:		
Construct new facility	☐	☐
If infeasible, explain:		
Modify existing facility	☐	☐
If infeasible, explain:		
Lease off-base facility	☐	☐
If infeasible, explain:		
Change operations	☐	☐
If infeasible, explain:		
Other ____________________	☐	☐

STEP 3: CALCULATING LIFE-CYCLE COSTS

After selecting alternatives for analysis, the next step is to collect data and identify the assumptions you will use for calculating the life-cycle costs of each alternative being analyzed. Life-cycle costs include the initial investment for any construction being programmed (e.g., an MCP or major repair project) and anticipated O&M costs over the life of the facility, generally assumed to be 50 years. Fifty years is a more realistic estimate of facility life than 25 years, which is often used in economic analyses. It also allows most major repair and replacement items to be included in the analysis, several of which have a life cycle of more than 25 years.

Life-cycle costs must be calculated for all alternatives, including the status quo. If a requirement changes and the alternatives being considered to meet the new requirement will also affect an existing operation, the costs associated with the existing operation must be included in the analysis. For example, a new mission may bring an additional 1,000 personnel on base, yet the existing dormitories are already filled to capacity. If a new dormitory is proposed to meet *only* the additional demand, the economic analysis would not include the costs associated with the existing dormitories. If, however, the proposed complex is expected to *replace* the existing facilities as well as to meet the increased demand, the costs of the status quo must be calculated. These costs are then assumed to be replaced by the life-cycle costs of the proposed complex and emerge as a savings achieved by implementing the project (see Step 5).

Since the economic analysis predicts *future* costs, there is an element of uncertainty about the data you will be using. Even if you use actual cost data from past projects, you are *assuming* that these data are an accurate estimate of what you can expect in the future. Thus, all data used in calculating life-cycle costs are actually assumptions. Similarly, if you use average costs, you are assuming that the actual cost of a facility being evaluated will be identical to those average costs. Obviously, you cannot be certain that will be the case, but making assumptions based on the best information available allows you to proceed with the analysis and is perfectly valid *provided the assumptions are consistent across alternatives.*

Construction costs used in this analysis are derived from AF Form 1178 as depicted on DD Form 1391. Future O&M costs can be calculated using Worksheets 1 through 6 in Appendix E of this manual. All costs over the life of each alternative should be included in the life-cycle cost analysis except sunk costs. Sunk costs are expenditures made before a decision to proceed with a project that could not be recovered if a project were not selected, including design costs and the costs of preparing the economic analysis. In other words, money that will already have been spent when the decision is made whether or not to approve a project for funding should not be included in the economic analysis.

Selecting the best assumptions for an economic analysis depends on *constraints* in the data available. The more specific the available data is to your circumstances, the more accurate it is likely to be. However, if specific data are not available, you may have to rely on general data sources. Appendix B provides more guidance on data sources for O&M costs. If the recommended data sources are not available at your base or in your area, the data base provided in Appendix B can be used for the analysis. If you use this data base, be sure to so indicate on the worksheets.

All assumptions, calculations, and data sources used to estimate the future costs associated with each of the alternatives should be documented on worksheets. Each worksheet provides space for such information, and you can use the back of the worksheets or additional pages if you need more space. Below is a completed example of that portion of the worksheet.

The major life-cycle cost elements that each worksheet covers are

> **Assumptions, Additional Calculations, and Data Sources:**
> Energy consumption data from Engineering Technical Letter (ETL) 86-1; percentage breakdown between electricity and natural gas usage was based on "Storage Type Facilities & Maintenance Facilities" for 1000<HDD<4000 since base is in Region 4.

1. Worksheet 1 - Annual Maintenance Costs
2. Worksheet 2 - Periodic Maintenance, Repair, and Replacement Costs
3. Worksheet 3 - Utility Costs

4. Worksheet 4 - Miscellaneous Operations and Maintenance Costs (optional)
5. Worksheet 5 - Miscellaneous User Costs (optional)
6. Worksheet 6 - Lease Costs

As a guide, the worksheets present at least one method for estimating costs for each cost element. These methods are used in most economic analyses; however, others may be used if they are more appropriate, based on the historical data available. If other methods are used, the calculations should be shown on the worksheets. Complete only the cost elements that apply to the alternatives being considered; it may not be necessary to complete all the worksheets. Worksheets 4 and 5 are both optional and should be completed only if the costs they address are expected to differ significantly among alternatives.

Potential sources for the data requirements that are in bold print on the worksheets are listed in Appendix B. Reliable data from on-base sources or the major command are preferred and should be used whenever possible. In case the appropriate data are not available from either on-base sources or the major command, the default values provided in Appendix B can be used.

All life-cycle costs must be put on a common baseline so they can be combined and compared. The baseline used for the economic analysis is the program year of the potential project; that is, the expected year of funding. If historic cost data are used, they must be converted to program-year dollars using the appropriate OSD inflators *before* they are used in the worksheets. Current OSD inflators are provided in Appendix C; updated figures are distributed to ACC periodically. They are also circulated annually with Air Staff guidance on MCP submittals. The totals from each worksheet are transferred to the appropriate columns on Form S-1 *for each year in the life-cycle analysis.*

The following sections describe how each of the worksheets and Form S-1 are completed. Each section also includes an example of a completed worksheet. The examples are from an economic analysis evaluating a new supply warehouse.

WORKSHEET 1: ANNUAL MAINTENANCE COSTS

Worksheet 1 is designed to estimate the routine maintenance costs that occur annually for each alternative (major maintenance, repair, and replacement items are calculated separately in Worksheet 2). Annual maintenance costs for existing facilities can usually be obtained by multiplying the number of square feet in the facility by the historic average annual maintenance cost per square foot for all on-base facilities in the same category code. Annual maintenance costs for new facilities can be estimated using historical average annual maintenance costs of similar existing facilities at the time of construction.

If enough historic data are available, it may be possible to determine that annual maintenance costs change over time as a facility ages. If the data indicate that maintenance costs change at a constant rate, an average annual rate of change can be calculated for the 50-year life of the facility. If the data indicate the change is variable over time, different average annual rates of change can be used over the 50-year life of the facility. An example of a completed Worksheet 1 is shown below. In the example, the $72,450 total maintenance costs are transferred to column (1) of Form S-1 for years 1 through 5. They are then escalated every 10 years by the percentages indicated on the worksheet. The escalation factor represents increased maintenance expected to be required as the building ages. *Escalation is not the same as inflation*, which represents increased costs of conducting the same level of maintenance.

WORKSHEET 1
Annual Maintenance Costs
(In Program-Year Dollars)
Alternative: **NEW CONSTRUCTION**

Annual Maintenance

Annual Maintenance Cost per Square Foot		$.69
Number of Square Feet of Building Space	(X)	105,000
Total Annual Maintenance Cost	(=)	$72,450

Escalation Factor (Method 1 - Building Age Multiplier)

Year of Construction or Renovation of Facility:	1990	
Building Age Multiplier During Years:	1991-1999	1.00
Building Age Multiplier During Years:	2000-2009	1.40
Building Age Multiplier During Years:	2010-2019	1.90
Building Age Multiplier During Years:	2020-2029	2.10
Building Age Multiplier During Years:	2030-2040	2.10

WORKSHEET 2: PERIODIC MAINTENANCE, REPAIR, AND REPLACEMENT COSTS

Worksheet 2 is designed to estimate the major maintenance, repair, and replacement items not included in Worksheet 1. In Worksheet 2, historic square-foot costs are used to estimate future costs for each alternative. (Remember to use the appropriate square footage: building space for electrical, heating, ventilation, and air conditioning (HVAC), plumbing, and floor maintenance and repair; exterior wall space for exterior closure and finishes; and the like.) If historic square-foot costs are unavailable or believed inaccurate, other cost-estimating techniques may be used (for example, Means or Dodge construction cost manuals or Appendix B). Historic data may indicate the life expectancy of each major repair item. For example, the life expectancy of a roof can be assumed to be the period between the last two roof repairs of the facility or of a similar facility. Appendix B also includes typical life expectancies for major building systems.

An example of a completed portion of Worksheet 2 follows. Note that the total costs shown are for *each* occurrence, so they would be added to each of the years noted. Costs from Worksheet 2 are totaled by year and transferred to column (2) of Form S-1.

WORKSHEET 2
Periodic Maintenance, Repair, and Replacement Costs
(In Program-Year Dollars)
Alternative: NEW CONSTRUCTION

Foundations, Floors, Structural Walls, Roof Structures, Stairs

M&R Cost per Square Foot		N/A
Number of Square Feet of ________ Space	(X)	N/A
Subtotal M&R Cost	(=)	N/A
Life Expectancy: 75 Years		
Years M&R Would Be Required		

Roofing

M&R Cost per Square Foot		$9.00
Number of Square Feet of Building Space	(X)	105,000
Subtotal M&R Cost	(=)	$945,000
Life Expectancy: 15 Years		
Years M&R Would Be Required 2005, 2020, 2035		

Interior Walls and Doors, Windows, Exterior Closure

M&R Cost per Square Foot		$11.36
Number of Square Feet of Building Space	(X)	105,000
Subtotal M&R Cost	(=)	$1,192,800
Life Expectancy: 50 Years		
Years M&R Would Be Required 2040		

WORKSHEET 3: UTILITY COSTS

Worksheet 3 estimates both energy-related and other utility costs. Energy costs for existing facilities can be estimated using historic consumption figures for the base. (The worksheet is designed for facilities that are not individually metered, which includes most Air Force facilities; for facilities that are individually metered, the first two lines of each utility cost category do not need to be completed.) Energy-related consumption figures must be converted to thousands of British thermal units (Btus) before calculating costs on the worksheet. Energy consumption and conversion factors can be obtained from the base energy office, local energy suppliers, or Appendix B.

After converting historic energy consumption figures to thousands of Btus, divide them by the total number of square feet in the facilities involved (e.g., if total energy consumption for all housing units on base is available, divide that by the total number if square feet in base housing) to obtain the average annual consumption in thousands of Btus by square foot of building space. This figure is then assumed to be the average annual per-square-foot use for the status quo.

For new facilities, energy consumption estimates are mandated by Engineering Technical Letter 86-1, which sets energy budget figures (EBFs) for new construction. The EBFs are set at 50 percent of average energy consumption rates for similar facilities in 1975. Therefore, one can assume that facilities built before 1975 consume twice as much energy as new facilities designed to the EBF. (If actual status quo consumption rates are unavailable and the status quo facilities were constructed before 1975, this assumption can also be used to estimate status quo consumption.) Energy consumption rates for renovated facilities depend on whether the renovation project includes energy conservation measures. If so, EBFs can also be used for alternatives involving renovation. (See Appendix B for further discussion of energy consumption.) The EBF is a *Btu* per square foot measure -- remember to convert to *thousands of Btus* by dividing the Btu figure by 1,000 before using it in Worksheet 3.

Other alternatives may require various assumptions to obtain consumption estimates in thousands of Btus per square foot. For alternatives involving facilities leased off base, historic energy consumption data would be available from local energy suppliers.

An example of a completed portion of the energy section of Worksheet 3 is shown below:

WORKSHEET 3
Utility Costs
(In Program-Year Dollars)
Alternative: NEW CONSTRUCTION

Electricity		
Consumption per Square Foot (in thousands of Btus)		12.6
Number of Square Feet of Building Space	(X)	105,000
Annual Electricity Consumption (in thousands of Btus)	(=)	1,323,000
Cost per Thousand Btus	(X)	$.02698
Total Annual Electricity Cost	(=)	$35,695
Natural Gas		
Consumption per Square Foot (in thousands of Btus)		2.4
Number of Square Feet of Building Space	(X)	105,000
Annual Natural Gas Consumption (in thousands of Btus)	(=)	252,000
Cost per Thousand Btus	(X)	$.00806
Total Annual Natural Gas Cost	(=)	$2,031

Water and sewage treatment costs are estimated in a manner similar to energy costs. Annual water use may be a variable of the number of square feet of building space, the number of personnel, or the number and kind of equipment pieces in a facility, depending on the type of facility being analyzed. For example, water consumption in a dormitory or office would most likely vary depending on the number of personnel using the facility, and water use in a vehicle maintenance facility would most likely change based on the number and types of equipment handled. Whatever unit of measurement is used, multiply the total annual water use for each alternative by the average cost per gallon of water on the base. The average cost per gallon of water on the base is available from the Civil Engineering Cost Report (RCS HAF LEE [SA] 7101).

The number of gallons of sewage treatment can be derived from the number of gallons of water use. The percentage of sewage treatment required per gallon of water use and the cost per gallon of sewage treatment are also available from the Civil Engineering Cost Report.

An example of the water and sewage treatment sections of Worksheet 3 is shown below.

WORKSHEET 3
Utility Costs
(In Program-Year Dollars)
Alternative: NEW CONSTRUCTION

Water		
Number of Units (e.g., square feet, personnel, equipment)		46
Annual Water Use per Unit (in thousands of gallons)	(X)	12.75
Total Annual Water Use	(=)	587
Cost per Thousand Gallons of Water	(X)	$.41
Total Annual Water Cost	(=)	$240
Sewage Treatment		
Total Annual Water Use (from water calculations above)		587
Ratio of Sewage Treatment to Water Use	(X)	70%
Total Annual Sewage Treatment	(=)	411
Cost per Thousand Gallons of Sewage Treatment	(X)	$1.05
Total Annual Sewage Treatment Cost	(=)	$431

Costs on Worksheet 3 are totaled and transferred to column (3) of Form S-1.

WORKSHEET 4: MISCELLANEOUS OPERATIONS AND MAINTENANCE COSTS (OPTIONAL)

Worksheet 4 is optional and should be completed only if costs are expected to differ significantly between alternatives. These costs include protective storage, trash removal, grounds maintenance, and custodial services. Protective storage costs are included for alternatives involving replacement of an existing facility that will not be demolished or converted to another use (see Step 2). An example of the protective storage portion of Worksheet 4 follows.

WORKSHEET 4 (OPTIONAL)
Miscellaneous Operations and Maintenance Costs
(In Program Year Dollars)
Alternative: Lease - Off-Base Storage Facility

Protective Storage-Initial One-Time Costs		
-Board Up Doors and Windows		$4,500
-Disconnect Utilities	(+)	$1,300
-Minor Repair	(+)	$5,000
-Other ______________	(+)	$0
Total One-Time Cost	(=)	$10,800
Protective Storage-Annual Operations and Maintenance Costs		
Annual Operations and Maintenance Cost Per Square Foot		$.89
Number of Square Feet	(X)	3,600
Total Annual Cost	(=)	$3,204

Trash removal and custodial services costs may differ substantially between competing alternatives if the sizes of the facilities under analysis vary widely or if one alternative involves leased facilities. A completed example of the trash removal portion of Worksheet 4 is shown below:

Trash Removal	Trash Containers Emptied Daily		
~~Annual Tons Generated per Unit (e.g., square feet, personnel)~~	^		6
~~Cost per Ton For Removal~~	Cost Per Container for Removal	(X)	$5.39
~~Annual Cost per Unit~~	Daily Removal Cost	(=)	$32.34
~~Number of Units~~	Number of Working Days per Year	(X)	255
Total Annual Cost		(=)	$8,247

Total miscellaneous O&M costs are transferred from Worksheet 4 to column (4) of Form S-1.

WORKSHEET 5: MISCELLANEOUS USER COSTS (OPTIONAL)

Worksheet 5 is also optional and should be completed only if costs are expected to differ significantly between alternatives. This worksheet covers transportation, furniture, fixtures, equipment, and other costs such as security. These costs may be estimated based on number of rooms, personnel, or pieces of equipment, or they may involve specific equipment purchases. Completed portions of this worksheet are shown below. Costs from Worksheet 5 are transferred to column (5) of Form S-1.

WORKSHEET 5 (OPTIONAL)
Miscellaneous User Costs
(In Program-Year Dollars)
Alternative: NEW CONSTRUCTION

Transportation

Annual Amount of Vehicle or Equipment Use (in miles or hours)		15,000
Cost per Mile or Hour	(X)	$.281
Total Annual Cost	(=)	$4,215

Furniture, Fixtures and Equipment (Method 1 - Average Cost per Unit)

Number of Units (e.g., rooms, offices or personnel)		N/A
Annual Furniture, Fixtures and Equipment Cost per Unit	(X)	N/A
Total Annual Cost	(=)	N/A

Furniture, Fixtures and Equipment (Method 2 - Itemized Costs)

Items Required	Life Expectancy	Years Required	Cost
Fork Lifts	20 Years	1991, 2011, 2031	$210,000

WORKSHEET 6: LEASE COSTS

Worksheet 6 is used to estimate facility lease and temporary lodging costs. Lease costs are associated with using off-base facilities. It is important to note whether or not the annual lease cost per square foot is the gross lease cost (which would indicate that the lessor would pay for maintenance, repair, custodial services, and utilities) or the net lease cost (which would indicate that those costs are the responsibility of the lessee). As indicated in the footnote on Worksheet 6, if the annual lease cost per square foot is net, costs associated with maintenance and repair, custodial services, and utilities must be estimated for this alternative on Worksheets 1, 2, 3, and 4.

The temporary lodging portion of Worksheet 6 is designed to estimate costs associated with temporary housing of personnel off base. For instance, if a new visiting officers quarters is proposed as an MCP project, the costs of housing personnel off base, either in contract quarters or other hotels, can be estimated on Worksheet 6. Associated transportation costs should be included on Worksheet 5.

A completed portion of Worksheet 6 is shown below. Costs from this worksheet are transferred to column (6) of Form S-1.

WORKSHEET 6
Lease Costs
(In Program Year Dollars)
Alternative: LEASE

Lease		
Annual Lease Cost Per Square Foot *		$.83
Number of Square Feet	(X)	105,000
Total Annual Cost	(=)	$87,150
On Base Quarters		
Number of Personnel Housed in On Base Quarters Per Year		
Average Room Rate Plus Per Diem	(X)	
Total Annual Cost **	(=)	

FORM S-1: LIFE-CYCLE COSTS SUMMARY

Form S-1 is used to sum all the life-cycle costs from the worksheets and to calculate the present value of future costs. For most projects, the period of analysis is 50 years of use, not including construction. All alternatives must be evaluated over the same period. If facility alternatives are expected to have different life cycles, you must show how the using function will continue to operate (e.g., replace facility) through the entire analysis period. This period should begin in the same year for each alternative to provide a common basis for comparison. The program year is separated out on Form S-1. It is assumed to be the year of construction, and construction costs are included in column (7) of that year. The second row starts the first year of occupancy, which is also the initial year that O&M costs are included. If construction is expected to take more than one year or is not expected to occur within the program year, construction costs should be included in the totals for later years, and O&M costs should begin after construction has been completed.

To complete Form S-1 for each of the alternatives, enter the life-cycle costs for each year from Worksheets 1 through 6 in columns (1) through (6). Place total life-cycle costs for each year in column (7). The present value of life-cycle costs is then calculated by multiplying the yearly totals in column (7) by the multipliers in column (8) and noting the result in column (9). Column (10) is used for a running cumulative total present value. This allows you to determine the break-even point between alternatives by noting when the cumulative costs of the alternatives converge (see Step 5).

A completed Form S-1 is shown on the following page. In this example, the programmed amount for construction, $7,600,000, is included in the total costs for the program year (1990). Annual maintenance costs begin at $72,450 to accrue in 1991, which is the first year of occupancy, and total $6,237,945 over the life of the project in constant program-year dollars. In column (2), periodic maintenance and repair costs are expected starting in 2000. Total periodic maintenance and repair costs are estimated at $11,140,500. All other costs, shown in columns (3), (4), (5), and (6), are expected to remain constant over the life of the facility. The total present value for the facility ($10,193,943) is shown at the bottom of column (9).

FORM S-1
Total Life-Cycle Costs
Alternative: NEW CONSTRUCTION

Fiscal Year	(1) Annual Maintenance (Worksheet 1)	(2) Periodic M&R (Worksheet 2)	(3) Utilities (Worksheet 3)	(4) Misc. O&M (Worksheet 4)	(5) Misc. User (Worksheet 5)	(6) Lease (Worksheet 6)	(7) Total Sum (1)-(6)	(8) Present Value Mult. (10% Disc.)	(9) Present Value (7) x (8)	(10) Cumulative Present Value (Annual Sum)
*1990							$7,600,000	1.000	$7,600,000	$7,600,000
**1991	$72,450	$0	$38,397	$16,857	$214,215	$0	$341,919	.909	$310,835	$7,910,835
1992	$72,450	$0	$38,397	$16,857	$4,215	$0	$131,919	.826	$109,024	$8,019,859
1993	$72,450	$0	$38,397	$16,857	$4,215	$0	$131,919	.751	$99,113	$8,118,972
1994	$72,450	$0	$38,397	$16,857	$4,215	$0	$131,919	.683	$90,102	$8,209,074
1995	$72,450	$0	$38,397	$16,857	$4,215	$0	$131,919	.621	$81,911	$8,290,986
1996	$72,450	$0	$38,397	$16,857	$4,215	$0	$131,919	.564	$74,465	$8,365,450
1997	$72,450	$0	$38,397	$16,857	$4,215	$0	$131,919	.513	$67,695	$8,433,146
1998	$72,450	$0	$38,397	$16,857	$4,215	$0	$131,919	.467	$61,541	$8,494,687
1999	$72,450	$0	$38,397	$16,857	$4,215	$0	$131,919	.424	$55,946	$8,550,633
2000	$101,430	$601,650	$38,397	$16,857	$4,215	$0	$762,549	.386	$293,996	$8,844,629
2001	$101,430	$0	$38,397	$16,857	$4,215	$0	$160,899	.350	$56,394	$8,901,023
2002	$101,430	$0	$38,397	$16,857	$4,215	$0	$160,899	.319	$51,267	$8,952,290
2003	$101,430	$0	$38,397	$16,857	$4,215	$0	$160,899	.290	$46,607	$8,998,897
2004	$101,430	$0	$38,397	$16,857	$4,215	$0	$160,899	.263	$42,370	$9,041,267
2005	$101,430	$945,000	$38,397	$16,857	$4,215	$0	$1,105,899	.239	$264,743	$9,306,010
2006	$101,430	$0	$38,397	$16,857	$4,215	$0	$160,899	.218	$35,016	$9,341,026
2007	$101,430	$0	$38,397	$16,857	$4,215	$0	$160,899	.198	$31,833	$9,372,859
2008	$101,430	$0	$38,397	$16,857	$4,215	$0	$160,899	.180	$28,939	$9,401,798
2009	$101,430	$0	$38,397	$16,857	$4,215	$0	$160,899	.164	$26,308	$9,428,107
2010	$137,655	$708,750	$38,397	$16,857	$4,215	$0	$905,874	.149	$134,652	$9,562,759
2011	$137,655	$0	$38,397	$16,857	$214,215	$0	$407,124	.135	$55,015	$9,617,774
2012	$137,655	$0	$38,397	$16,857	$4,215	$0	$197,124	.123	$24,216	$9,641,990
2013	$137,655	$0	$38,397	$16,857	$4,215	$0	$197,124	.112	$22,014	$9,664,004
2014	$137,655	$0	$38,397	$16,857	$4,215	$0	$197,124	.102	$20,013	$9,684,017
2015	$137,655	$1,309,350	$38,397	$16,857	$4,215	$0	$1,506,474	.092	$139,042	$9,823,059

* Program year; include capital investment in first row of Column 7.

** First year of occupancy.

(page 1 of 2)

FORM S-1
Total Life-Cycle Costs
Alternative: NEW CONSTRUCTION

Fiscal Year	(1) Annual Maintenance (Worksheet 1)	(2) Periodic M&R (Worksheet 2)	(3) Utilities (Worksheet 3)	(4) Misc. O&M (Worksheet 4)	(5) Misc. User (Worksheet 5)	(6) Lease (Worksheet 6)	(7) Total Sum (1)-(6)	(8) Present Value Mult. (10% Disc.)	(9) Present Value (7) x (8)	(10) Cumulative Present Value (Annual Sum)
2016	$137,655	$0	$38,397	$16,857	$4,215	$0	$197,124	.084	$16,540	$9,839,599
2017	$137,655	$0	$38,397	$16,857	$4,215	$0	$197,124	.076	$15,036	$9,854,635
2018	$137,655	$0	$38,397	$16,857	$4,215	$0	$197,124	.069	$13,669	$9,868,304
2019	$137,655	$0	$38,397	$16,857	$4,215	$0	$197,124	.063	$12,427	$9,880,731
2020	$152,145	$2,347,800	$38,397	$16,857	$4,215	$0	$2,559,414	.057	$146,676	$10,027,407
2021	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.052	$11,025	$10,038,432
2022	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.047	$10,023	$10,048,454
2023	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.043	$9,111	$10,057,566
2024	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.039	$8,283	$10,065,849
2025	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.036	$7,530	$10,073,379
2026	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.032	$6,846	$10,080,224
2027	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.029	$6,223	$10,086,448
2028	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.027	$5,657	$10,092,105
2029	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.024	$5,143	$10,097,248
2030	$152,145	$708,750	$38,397	$16,857	$4,215	$0	$920,364	.022	$20,335	$10,117,584
2031	$152,145	$0	$38,397	$16,857	$214,215	$0	$421,614	.020	$8,469	$10,126,052
2032	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.018	$3,864	$10,129,916
2033	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.017	$3,513	$10,133,429
2034	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.015	$3,193	$10,136,623
2035	$152,145	$945,000	$38,397	$16,857	$4,215	$0	$1,156,614	.014	$15,868	$10,152,491
2036	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.012	$2,639	$10,155,130
2037	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.011	$2,399	$10,157,529
2038	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.010	$2,181	$10,159,710
2039	$152,145	$0	$38,397	$16,857	$4,215	$0	$211,614	.009	$1,983	$10,161,693
2040	$152,145	$3,574,200	$38,397	$16,857	$4,215	$0	$3,785,814	.009	$32,250	$10,193,943
Total	$6,237,945	$11,140,500	$1,919,860	$842,835	$840,750	$0	$28,581,890		$10,193,943	

(page 2 of 2)

CHECKLIST

STEP 3: CALCULATING LIFE-CYCLE COSTS

Cost components:

By year in constant, program-year dollars

Construction/initial investment -- DD Form 1391

Annual maintenance -- Worksheet 1

Periodic maintenance, repair, and replacement -- Worksheet 2

Utilities (including energy) -- Worksheet 3

Miscellaneous O&M -- Worksheet 4
(e.g., protective storage, trash removal, and custodial services)

Miscellaneous user costs -- Worksheet 5
(e.g., security and transportation)

Lease (also temporary lodging) -- Worksheet 6

Life-cycle costs (in present value) -- Form S-1

Total cost (by year) x present-value multipliers

STEP 4: EVALUATING BENEFITS

The life-cycle cost calculations are a means of comparing alternatives based on anticipated costs over their useful life. That assumes that all alternatives provide the same benefits, however, which is not always the case. For example, one alternative may be expected to increase productivity or efficiency more than another. Benefits should also be taken into consideration when deciding among alternatives.

Benefits can be quantitative (measurable) or qualitative. This manual provides methods for incorporating either or both in the economic analysis. These methods are optional. Their use is recommended as a supplement to the life-cycle cost analysis when projects are being proposed particularly to improve existing conditions, and cost is not the only consideration. Quantitative benefits include increases in productivity and user savings. Productivity increases are changes in *output* (e.g., accomplishing more with available resources). User cost savings are changes in *input* (e.g., labor and materials) required to perform a mission. Worksheet 7 is used to calculate quantitative benefits, and the results are summarized on Form S-2. Worksheet 8 is used to determine qualitative benefits.

WORKSHEET 7: QUANTITATIVE BENEFITS (OPTIONAL)

Worksheet 7 includes calculations for increases in productivity, personnel savings, fuel savings, and other savings. These savings are accrued by the *user*; savings in the life-cycle costs of the facility itself (e.g., O&M costs) are evident from the life-cycle cost analysis in Step 3 and are not included in the benefits analysis.

Increases in productivity should be calculated only if output is expected to increase. Personnel savings, on the other hand, should be calculated only if personnel costs are expected to decrease. If output is expected to increase *and* personnel costs are expected to go down, the combined benefit can be calculated using the increase in productivity part of the worksheet. Savings in the fuel costs or other costs are also included in the analysis only if the user's costs of doing business are expected to decrease. *User costs incorporated in the life-cycle cost analysis (using Worksheet 5) should not also be counted in the benefits analysis.*

Benefits associated with increased productivity are based on a unit of output. Examples of outputs for various types of facilities are

1. aircraft maintenance facility -- number of repair or maintenance jobs;

2. vehicle painting facility -- number of vehicles painted;

3. educational facility -- number of students trained;

4. warehouse facility -- number of supply requests filled;

5. sewage treatment plant -- number of gallons of treated sewage;

6. electrical power plant -- number of kilowatt-hours of electricity produced;

7. dormitory -- number of personnel housed; and

8. visiting officers quarters -- number of transient room-nights.

The status quo is used as the baseline against which the productivity benefits of all other alternatives are compared. For example, if an existing facility is renovated or a new facility is constructed to replace a deficient one, the user may benefit from an increase in overall productivity. This may be due to a space increase, updated equipment, consolidation of similar facilities, or other features specifically designed to increase productivity.

To calculate productivity benefits, you must (1) select an appropriate unit of output, (2) determine the current level of output under the status quo, and (3) estimate the increased level of output expected under the alternatives to the status quo. In many cases, projects are considered specifically to accommodate an increased need, which becomes the expected level of output under the alternatives to the status quo. For instance, if a base receives a new mission that requires an increase in aircraft maintenance (e.g., 20 aircraft must be maintained as opposed to 10) the level of output associated with each of the alternatives considered would be 20 aircraft, and the status quo level of output is 10.

In cases in which a specific level of output is not mandated, however, estimating the benefits of a project may require various assumptions regarding the increase in productivity of personnel in a different work space. For example, historical data may indicate that an existing supply warehouse fills only 35 percent of its requests within one month. The reason it is not adequately meeting the demand is a shortage of space and equipment. Therefore, a project is proposed to provide a new warehouse with more space and modern equipment. If, across the Air Force, supply organizations fill an average 74 percent of their request within one month, one can assume that the proposed warehouse would also be able to fill 74 percent of the supply request within one month.

The expanded output or service must meet a demand; otherwise, it cannot be considered a benefit. The benefit associated with a new hangar capable of maintaining 20 aircraft cannot be considered a benefit if the base has only 10 aircraft that require maintenance. Increases in demand may be phased over more than one year. For instance, a base may be scheduled to receive five additional aircraft per year over four years. In that case, the quantity of benefit calculated for each year should reflect the phasing. *All assumptions regarding service and output levels must be noted and sources of historical data must be documented on Worksheet 7.*

To calculate benefits from increased productivity using Worksheet 7, first estimate the average annual level of output for the status quo and then determine what the total annual personnel costs are to produce that output. Note that the labor costs are calculated in burdened labor rates, which include benefits as well as direct salaries. Divide the total personnel costs by the level of output to derive the per-unit cost of the status quo production. Perform the same calculations for the alternative, using expected new level of output and personnel costs. Subtract the cost per unit of output for the alternative from the cost per unit of output for the status quo to derive the incremental benefit per unit of output. Multiply the result by the number of units of output expected with the alternative to obtain the total annual benefit. The calculation is represented by the following equation:

$$B_{(A)} = [P_{(SQ)}/O_{(SQ)} - P_{(A)}/O_{(A)}] \times O_{(A)}$$

B = benefit from increase in productivity
P = personnel costs
O = level of output
SQ = status quo
A = alternative

This figure is then transferred to column (1) of Form S-2.

To calculate personnel savings with Worksheet 7, estimate the hours of labor that would be saved by implementing an alternative to the status quo. Multiply those hours saved by the average burdened salary (including benefits) of the personnel affected. To calculate fuel savings, estimate the gallons of fuel that would be saved and multiply by the price per gallon of fuel. Note that all costs are estimated in constant dollars using the same program year used for the life-cycle costs.

A completed example of Worksheet 7 is provided below. This example shows increases in productivity resulting from consolidating dispersed supply functions in a new warehouse.

WORKSHEET 7 (OPTIONAL)
Quantitative Benefits
(In Program-Year Dollars)
Alternative: NEW CONSTRUCTION

Increase in Productivity

Annual Labor Cost of Alternative		$920,000
Annual Output of Alternative	(/)	76,500
Average Labor Cost per Unit of Output of Alternative	(=)	$12.03
Annual Labor Cost of Status Quo		$920,000
Annual Output of Status Quo	(/)	61,965
Average Labor Cost per Unit of Output of Status Quo	(=)	$14.85
Average Labor Cost per Unit of Output of Alternative (from above)	(-)	$12.03
Average Labor Cost per Unit of Increased Output	(=)	$2.82
Annual Output of Alternative (from above)	(X)	76,500
Total Annual Benefit from Increase in Productivity	(=)	$215,802

Indirect effects, which are effects that the primary user's actions have on other operations, can also be incorporated in the benefits analysis. For instance, if the downtime of one operation affects the output of another operation, the effect can be quantified and included in the benefits calculation.

For example, an existing electrical generating facility may be archaic and cause frequent blackouts which interrupt the work of 10,000 personnel for an average of 12 hours per year. Some buildings are equipped with backup generators. An MCP project is proposed that is expected to decrease the total length of blackout periods to an average of 2 minutes per year. The benefits of this project would include saving the labor hours lost during blackouts under the status quo, as well as the fuel used by the backup generators.

Note that the benefit in that example is not measured in labor hours of workers at the electrical generating facility but in labor hours of workers in operations *affected* by the facility. Similarly, the savings in diesel fuel to power backup generators is counted as an *indirect* savings for other operations. Indirect savings can be calculated using Worksheet 7 in the same manner as direct savings.

Indirect cost savings are often hard to quantify and support with specific evidence. Sometimes, because of lack of information or time, it is not possible to quantify indirect benefits. For example, a supply warehouse that can fill only 35 percent of its supply requests within one month has a detrimental effect on all operations on the base that cannot obtain supplies in a timely manner. However, if a newly constructed supply warehouse is assumed to be able to fill 74 percent of its supply requests within a month, each operation on the base could receive an indirect benefit. To quantify this indirect benefit in labor or material savings would be extremely difficult. Nevertheless, it is an important consideration and should be included in the analysis as a quantitative benefit. Nonquantifiable indirect benefits can be included in the evaluation of qualitative benefits on Worksheet 8.

Once the value of the quantitative benefit has been calculated in constant-year dollars, it, like the life-cycle costs in Step 3, must be converted to present value. This is accomplished using Form S-2, which is similar to Form S-1. Transfer annual increases in productivity in constant dollars from Worksheet 7 to column (1) of Form S-2, personnel savings to column (2), fuel savings to column (3), and other savings to column (4). Add these columns across each year to derive total annual benefits for column (5). Multiply the annual benefits in column (5) by the discount multipliers in column (6) to derive the present value of the benefit for column (7). Use column (8) to run a cumulative total. An example of Form S-2 is provided on the following page.

WORKSHEET 8: QUALITATIVE BENEFITS (OPTIONAL)

Although quantifying the benefits of each alternative for the economic analysis is desirable, frequently the information required to do so is inadequate or not available. Some considerations, like morale and compatibility, cannot be reduced to dollars and cents. These considerations can nevertheless be important in decision making.

The qualitative analysis portion of the economic analysis allows factors not related to cost to be incorporated in the evaluation. Suitable qualitative factors are likely to change from project to project, so there are no universal, prescribed criteria for conducting the qualitative analysis. Some suggested criteria are provided in Appendix D. These are not intended as an exhaustive description of potential qualitative benefits, but they may be used as a guide in conducting the qualitative evaluation. Not all criteria need to be considered for every analysis; however, the same factors must be used for all alternatives within an individual

FORM S-2
Total Life-Cycle Benefits
Alternative: NEW CONSTRUCTION

Fiscal Year	(1) Increased Productivity (Worksheet 7)	(2) Personnel Cost Savings (Worksheet 7)	(3) Fuel Cost Savings (Worksheet 7)	(4) Other Cost Savings (Worksheet 7)	(5) Total Sum (1)-(4)	(6) Present Value Mult. (10% Disc.)	(7) Present Value (5) x (6)	(8) Cumulative Present Value (Annual Sum)
**1991	$215,802	N/A	$2,576	$5,000	$223,378	.909	$203,071	$203,071
1992	$215,802	N/A	$2,576	$5,000	$223,378	.826	$184,610	$387,681
1993	$215,802	N/A	$2,576	$5,000	$223,378	.751	$167,827	$555,508
1994	$215,802	N/A	$2,576	$5,000	$223,378	.683	$152,570	$708,078
1995	$215,802	N/A	$2,576	$5,000	$223,378	.621	$138,700	$846,779
1996	$215,802	N/A	$2,576	$5,000	$223,378	.564	$126,091	$972,870
1997	$215,802	N/A	$2,576	$5,000	$223,378	.513	$114,628	$1,087,498
1998	$215,802	N/A	$2,576	$5,000	$223,378	.467	$104,208	$1,191,705
1999	$215,802	N/A	$2,576	$5,000	$223,378	.424	$94,734	$1,286,440
2000	$215,802	N/A	$2,576	$5,000	$223,378	.386	$86,122	$1,372,561
2001	$215,802	N/A	$2,576	$5,000	$223,378	.350	$78,293	$1,450,854
2002	$215,802	N/A	$2,576	$5,000	$223,378	.319	$71,175	$1,522,029
2003	$215,802	N/A	$2,576	$5,000	$223,378	.290	$64,705	$1,586,734
2004	$215,802	N/A	$2,576	$5,000	$223,378	.263	$58,822	$1,645,556
2005	$215,802	N/A	$2,576	$5,000	$223,378	.239	$53,475	$1,699,031
2006	$215,802	N/A	$2,576	$5,000	$223,378	.218	$48,614	$1,747,645
2007	$215,802	N/A	$2,576	$5,000	$223,378	.198	$44,194	$1,791,839
2008	$215,802	N/A	$2,576	$5,000	$223,378	.180	$40,177	$1,832,015
2009	$215,802	N/A	$2,576	$5,000	$223,378	.164	$36,524	$1,868,540
2010	$215,802	N/A	$2,576	$5,000	$223,378	.149	$33,204	$1,901,743
2011	$215,802	N/A	$2,576	$5,000	$223,378	.135	$30,185	$1,931,928
2012	$215,802	N/A	$2,576	$5,000	$223,378	.123	$27,441	$1,959,370
2013	$215,802	N/A	$2,576	$5,000	$223,378	.112	$24,946	$1,984,316
2014	$215,802	N/A	$2,576	$5,000	$223,378	.102	$22,679	$2,006,995
2015	$215,802	N/A	$2,576	$5,000	$223,378	.092	$20,617	$2,027,612

** First year of occupancy.

(page 1 of 2)

FORM S-2
Total Life-Cycle Benefits
Alternative: NEW CONSTRUCTION

Fiscal Year	(1) Increased Productivity (Worksheet 7)	(2) Personnel Cost Savings (Worksheet 7)	(3) Fuel Cost Savings (Worksheet 7)	(4) Other Cost Savings (Worksheet 7)	(5) Total Sum (1)-(4)	(6) Present Value Mult. (10% Disc.)	(7) Present Value (5) x (6)	(8) Cumulative Present Value (Annual Sum)
2016	$215,802	N/A	$2,576	$5,000	$223,378	.084	$18,743	$2,046,354
2017	$215,802	N/A	$2,576	$5,000	$223,378	.076	$17,039	$2,063,393
2018	$215,802	N/A	$2,576	$5,000	$223,378	.069	$15,490	$2,078,883
2019	$215,802	N/A	$2,576	$5,000	$223,378	.063	$14,082	$2,092,964
2020	$215,802	N/A	$2,576	$5,000	$223,378	.057	$12,801	$2,105,766
2021	$215,802	N/A	$2,576	$5,000	$223,378	.052	$11,638	$2,117,404
2022	$215,802	N/A	$2,576	$5,000	$223,378	.047	$10,580	$2,127,983
2023	$215,802	N/A	$2,576	$5,000	$223,378	.043	$9,618	$2,137,601
2024	$215,802	N/A	$2,576	$5,000	$223,378	.039	$8,744	$2,146,345
2025	$215,802	N/A	$2,576	$5,000	$223,378	.036	$7,949	$2,154,293
2026	$215,802	N/A	$2,576	$5,000	$223,378	.032	$7,226	$2,161,520
2027	$215,802	N/A	$2,576	$5,000	$223,378	.029	$6,569	$2,168,089
2028	$215,802	N/A	$2,576	$5,000	$223,378	.027	$5,972	$2,174,061
2029	$215,802	N/A	$2,576	$5,000	$223,378	.024	$5,429	$2,179,490
2030	$215,802	N/A	$2,576	$5,000	$223,378	.022	$4,936	$2,184,425
2031	$215,802	N/A	$2,576	$5,000	$223,378	.020	$4,487	$2,188,912
2032	$215,802	N/A	$2,576	$5,000	$223,378	.018	$4,079	$2,192,991
2033	$215,802	N/A	$2,576	$5,000	$223,378	.017	$3,708	$2,196,699
2034	$215,802	N/A	$2,576	$5,000	$223,378	.015	$3,371	$2,200,070
2035	$215,802	N/A	$2,576	$5,000	$223,378	.014	$3,065	$2,203,135
2036	$215,802	N/A	$2,576	$5,000	$223,378	.012	$2,786	$2,205,921
2037	$215,802	N/A	$2,576	$5,000	$223,378	.011	$2,533	$2,208,453
2038	$215,802	N/A	$2,576	$5,000	$223,378	.010	$2,302	$2,210,756
2039	$215,802	N/A	$2,576	$5,000	$223,378	.009	$2,093	$2,212,849
2040	$215,802	N/A	$2,576	$5,000	$223,378	.009	$1,903	$2,214,752
Total	$10,790,123	N/A	$128,779	$250,000	$11,168,903		$2,214,752	

economic analysis. There is no limit to the number of qualitative factors that may be considered. If anticipated user savings or increases in productivity cannot be quantified, they, too, can be considered in the qualitative analysis.

The qualitative evaluation using Worksheet 8 is performed by scoring each alternative subjectively on a scale from 1, least effective, to 10, most effective. The scores can be weighted to reflect the relative importance of the criteria. For instance, if productivity is twice as important as maintainability, the productivity scores would be multiplied by 2 to obtain a weighted score. The weighted scores are then added together to get a total score for each alternative. The alternative with the highest score is the one that performs best with respect to qualitative considerations. An example of Worksheet 8 is provided below. The weighted scores from Worksheet 8 are transferred to Form S-3 for consideration in ranking alternatives.

WORKSHEET 8 (OPTIONAL)
Qualitative Benefits
Alternative: NEW CONSTRUCTION

Criteria (Specify)	Score	Weight	Weighted Score
Faster Response	10	3	30
Better Accountability	8	2	16
Sensitive Material Handling	7	2	14
Morale	10	1	10
Service & Maintainability	10	2	20
Land Use Compatability	10	1	10
Traffic Considerations	7	2	14
		Total	114

CHECKLIST

STEP 4: EVALUATING BENEFITS

Quantitative Benefits (Optional) --Worksheet 7

Increase in productivity

Difference in annual personnel costs per unit of output multiplied by total output of the alternative

Personnel cost savings

Number of hours saved multiplied by average burdened salary

Fuel cost savings

Gallons of fuel saved multiplied by cost per gallon

Other

Cost difference from status quo

Qualitative Benefits (Optional) -- Worksheet 8

Specify criteria	***Weight***
________________________________	______
________________________________	______
________________________________	______
________________________________	______
________________________________	______
________________________________	______

STEP 5: COMPARING COSTS AND BENEFITS OF ALTERNATIVES

A number of approaches can be used for comparing the costs and benefits of alternatives. These range from simply comparing the present value of life-cycle costs to identify the least-cost alternative to calculating a benefit-cost ratio that incorporates benefits as well. In addition to comparing total cost and benefits, present value can be used to determine the break-even point and payback period of alternatives relative to each other or to the status quo. Other optional calculations can be performed to estimate return on investment. These tools are described below.

BENEFIT-COST RATIO (OPTIONAL)

In an economic analysis, the primary basis of comparison between alternatives is present value. As described in the sections for Steps 3 and 4, total present value of costs is calculated on Form S-1 and total present value of benefits on Form S-2. Form S-3 is used to summarize these results and to integrate costs and benefits to derive the benefit-cost ratio (BCR), which may be calculated for each alternative except the status quo. The BCR of an alternative is calculated as the sum of the life-cycle costs of the status quo plus the total benefits of the alternative divided by the life-cycle costs of the alternative.

$$BCR_{(A)} = \frac{C_{(SQ)} + B_{(A)}}{C_{(A)}}$$

A = alternative
SQ = status quo
C = life-cycle cost (in present value)
B = life-cycle benefits (in present value)

The life-cycle costs of the status quo are included in the equation, because it is assumed that, if the alternative is implemented, those costs would be saved.

If the BCR for an alternative is greater than 1, the alternative provides greater quantifiable benefits relative to costs than does the status quo. The alternative with the largest BCR provides the greatest amount of quantifiable benefits relative to costs.

BCR is calculated on Form S-3. An example is provided below.

FORM S-3
Ranking Alternatives

	Status Quo	Alternative: Renovation	Alternative: New Construction
Life-Cycle Benefits (from FORM S-2)	N/A	$262,763	$2,214,752
Life-Cycle Costs of Status Quo (from FORM S-1)	N/A	(+) $8,368,989	(+) $8,368,989
Total Life-Cycle Benefit (Including Status Quo Cost Avoidance)	N/A	(=) $8,631,752	(=) $10,583,741
Total Life-Cycle Costs (from FORM S-1)	N/A	(/) $9,797,569	(/) $10,193,943
Benefit-Cost Ratio (BCR) *	1	(=) .88	(=) 1.04

BREAK-EVEN GRAPH (OPTIONAL)

The break-even graph is a useful way to summarize the results of the life-cycle cost analysis and to present them to decision makers. It allows decision makers to quickly see the relative performance of alternatives with respect to life-cycle costs, and it acts as an excellent "bottom-line" briefing chart. It is also a visual illustration of a project's payback period.

The payback period is the time it takes to recoup the initial cost of a project, represented by the point at which the present value of its life-cycle costs equals the present value of the life-cycle costs of the status quo. For example, an MCP project to construct a replacement facility may result in a saving of some of the O&M dollars it cost to keep the existing facility running. Over time, the money saved may equal the cost of building the new facility. This time is the payback period. This concept is illustrated by the cash flow diagram in Figure 2.

The payback period can be determined by comparing the cumulative totals in column (10) on Form S-1 for the status quo and the other alternatives. The year at

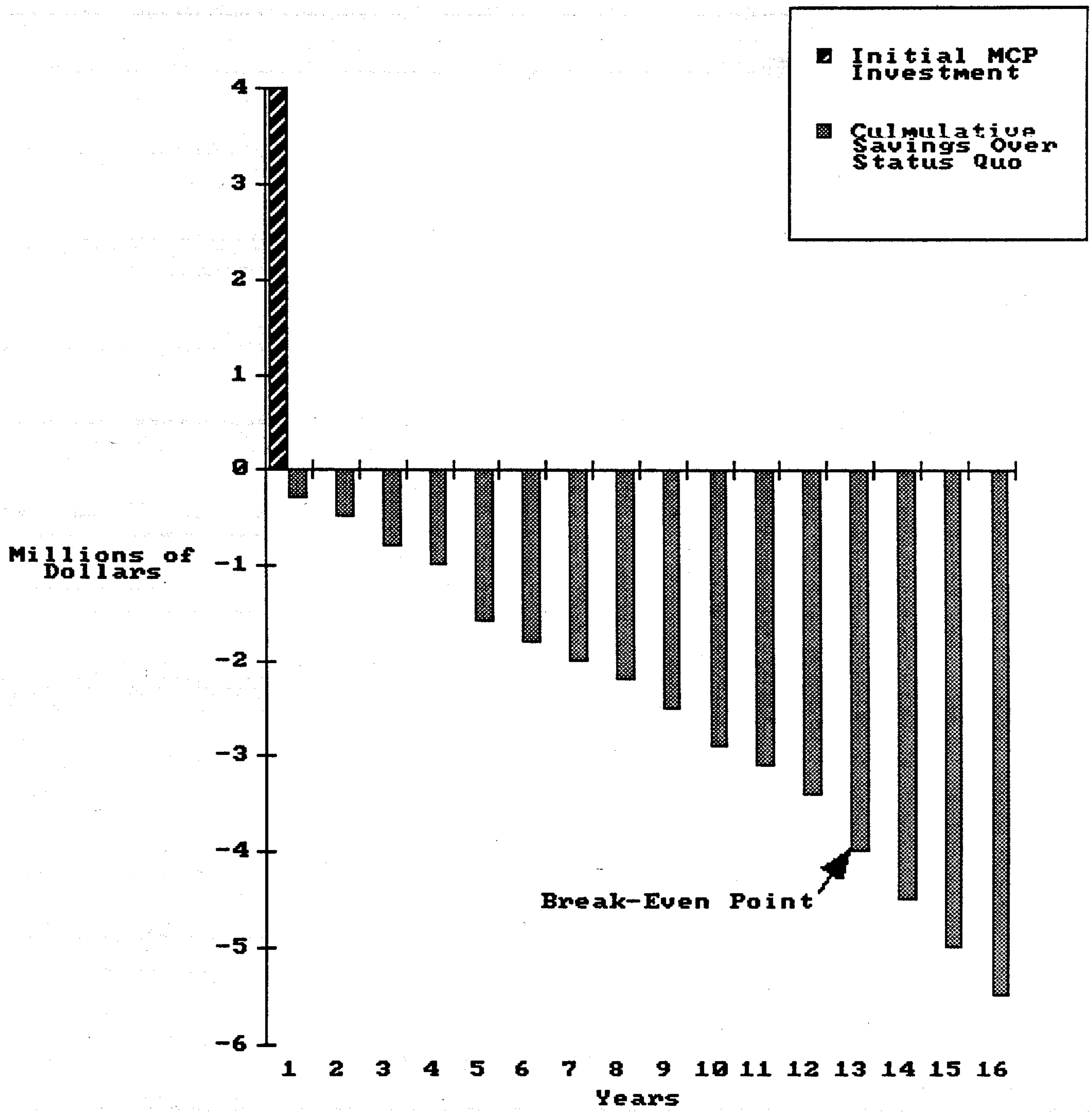
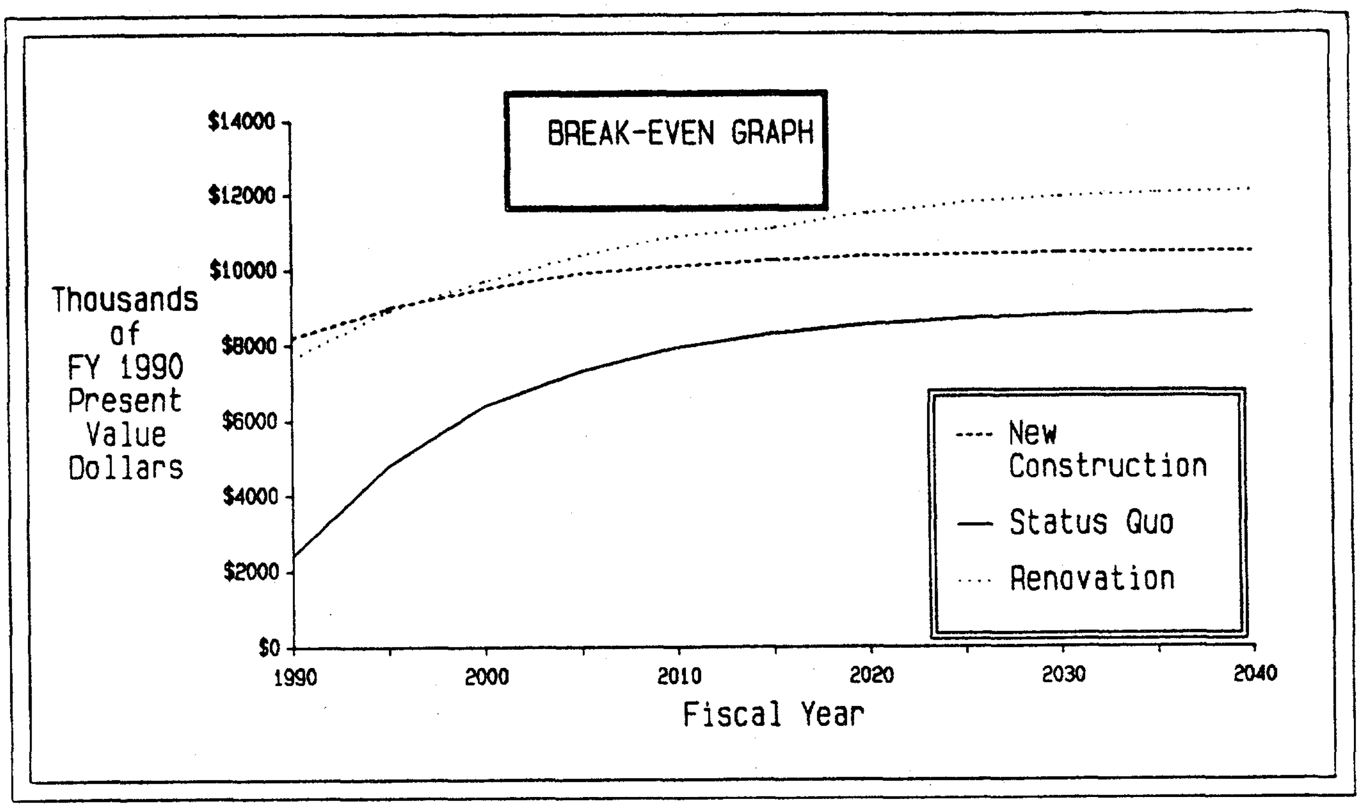


Figure 2

CASH FLOW DIAGRAM

which an alternative's cumulative present value is about the same or begins to be lower than that of the status quo is the end of the payback period for that alternative.

To illustrate the break-even point graphically, plot the cumulative present values from Form S-1 for each alternative on a graph, with time on the *X*-axis and cost on the *Y*-axis, and connect them with a line. The intersection between the two lines is the break-even point for those two alternatives. The number of years it takes to get to that intersection is the payback period. An example of a break-even graph is provided below.



SAVINGS-INVESTMENT RATIO (OPTIONAL)

Present value and BCR provide a basis of comparison for determining the least overall cost to the taxpayer of performing a mission. Other considerations may be important in deciding which alternative to select. For instance, if MCP funds are limited, the initial cost of construction may be an important consideration. The savings-investment ratio (SIR) can be used by a decision maker to determine if the base is getting the most for the year's MCP dollars.

The SIR is defined as the ratio of the project's life-cycle cost savings over the status quo, in present value, to initial investment cost (programmed amount). An SIR of 1 indicates that the present value of savings over the life of the facility equals the present value of the investment. An investment with an SIR greater than 1 is considered a good investment. The SIR is calculated as:

$$SIR_{(A)} = \frac{C_{(B)} - C_{(A)}}{PA_{(A)}}$$

$C_{(B)}$ = life-cycle cost of baseline, normally the status quo (in present value)
$C_{(A)}$ = life-cycle cost of alternative (in present value)
$PA_{(A)}$ = programmed amount of alternative (from DD Form 1391)

EFFICIENCY/PRODUCTIVITY-INVESTMENT RATIO (OPTIONAL)

The efficiency/productivity-investment ratio (EPIR) is similar to the SIR, except that it relates project benefits to initial investment costs. It is defined as the ratio of total benefits, in present value, over the initial investment (programmed amount). Using information from Form S-2 it is calculated as:

$$EPIR_{(A)} = \frac{B_{(A)}}{PA_{(A)}}$$

$B_{(A)}$ = life-cycle benefits of alternative (in present value)
$PA_{(A)}$ = programmed amount of alternative (from DD Form 1391)

RANKING ALTERNATIVES

As this manual demonstrates, a number of indicators can be considered in ranking alternatives, including life-cycle costs and benefits, return on investment, and qualitative factors. If these indicators are mutually supportive, the selection of a preferred alternative is relatively easy. If, however, different indicators favor different alternatives (e.g., one has the lowest life-cycle cost, another provides the highest SIR, and a third provides the most qualitative benefits), coming up with a ranking is more difficult. *Also, the findings of the economic analysis are not the only factors that enter into a programming decision.*

The most appropriate approach to ranking alternatives depends on the objectives of the economic analysis and the nature of the requirement that initiated it. For example, if the requirement is to reduce the cost of operating and maintaining a facility, the ranking may be based on life-cycle costs alone. If, on the other hand, the objective is to increase capability, the ranking may be based on a combination of costs and benefits. If some of the benefits cannot be translated into dollars, the qualitative evaluation may be considered in the ranking. Ranking based *solely* on qualitative factors is not recommended. Other guidelines include the following:

1. A requirement to correct a structural deficiency lends itself to a ranking based on highest BCR.

2. A requirement to correct a health or safety problem lends itself to a ranking based on quantitative and qualitative benefits.

3. A requirement to decrease O&M costs lends itself to a ranking based on least life-cycle costs or highest SIR.

4. A requirement to increase efficiency or productivity lends itself to a ranking based on highest BCR or EPIR.

5. A requirement to improve morale, retention, or quality of life lends itself to a ranking based on a combination of cost and qualitative factors.

6. A requirement that involves historic buildings or environmental considerations lends itself to a ranking based on a combination of cost and qualitative factors.

7. A requirement that has off-base impacts or implications lends itself to a ranking based on a combination of cost and qualitative factors.

CHECKLIST

STEP 5: COMPARING ALTERNATIVES

Optional Calculations

Benefit-Cost Ratio (BCR)

Equal to total life-cycle benefits divided by total life-cycle costs

1) If BCR > 1, the alternative is more cost-effective than the status quo.
2) If BCR < 1, the alternative is less cost-effective than the status quo.
3) The alternative with the largest BCR is the most cost-effective alternative.

Break-Even Graph

Plot cumulative life-cycle costs for each alternative on a graph

1) Illustrates which alternative has least life-cycle costs.
2) Illustrates point at which one alternative performs better than another.

Savings-Investment Ratio (SIR)

Equal to decrease in life-cycle costs from status quo divided by programmed amount

1) The alternative with the largest SIR offers the greatest return in savings per dollar of initial investment.

Efficiency/Productivity-Investment Ratio (EPIR)

Equal to total benefits divided by programmed amount

1) The alternative with the largest EPIR offers the greatest return in benefits per dollar of initial investment.

Qualitative Benefits

Score each applicable factor from 1 to 10

1) Scores can be weighted to reflect the priority of the factor.
2) Scores can be summed to obtain an overall qualitative rating.
3) The alternative with the highest score has the greatest qualitative benefits.

STEP 6: PERFORMING SENSITIVITY ANALYSES

Sensitivity analyses, which are optional, offer a way to test the reliability of your findings when uncertainties exist. "The element of uncertainty is always present in an economic analysis due to its basic futuristic orientation" (*Defense Economic Issues).* Sensitivity analyses show you how the results of the economic analysis might change if you change your assumptions. The primary objective in performing sensitivity analyses is to determine whether they will change the ranking of the alternatives. They also demonstrate to decision makers that uncertainties have been considered.

The conclusions of an economic analysis are only as good as the initial assumptions. If you are unsure about the data you used or the assumptions you made, you may want to perform a sensitivity analysis. Sensitivity analyses are also a good idea when the costs and benefits of alternatives are very close. If two or more alternatives have life-cycle costs within 15 percent of one another or if the break-even point is past 20 years, a sensitivity analysis should be considered.

Sensitivity analyses can be performed on life-cycle costs, life-cycle benefits, and qualitative factors. They are accomplished by changing one or more of the variables used in conducting the calculations. New calculations are performed using the same worksheets and forms used for the primary analysis. The variables that can be changed in the life-cycle cost and benefits calculations include

1. assumptions about costs,

2. inflation rates, and

3. the discount rate.

Changing the discount rate is the most common sensitivity analysis. The value of money, represented by interest rates, changes over time. The discount rate used in an economic analysis is the best guess of what average interest rates will be over the life of a project, but, like all predictions, it involves an element of uncertainty. Performing a sensitivity analysis allows you to test the effect a change in interest rates would have on the cost-effectiveness of your project. In general, using higher discount rates minimizes the effect of future costs, and initial investment costs have a greater impact on the results of the analysis. Using lower discount rates, on the other hand, increases the importance of long-term costs in the analysis.

A good alternate discount rate to use is the current interest rate on long-term U.S. Treasury securities, which is published regularly in economic publications such as the *Wall Street Journal. This rate includes inflation, however, so you must subtract from it the current rate of inflation to derive a real interest rate for the economic analysis.* The 10 percent discount rate used in this manual is already adjusted for inflation. Table C-2 in Appendix C provides multipliers for a number of different discount rates that can be used with Form S-1a for a sensitivity analysis. (Form S-1a is identical to Form S-1 except column (8) is blank, allowing for the use of different present value multipliers.)

If you calculate life-cycle *costs* using a different discount rate, remember to calculate the *quantitative benefits* using the same rate. *You can only compare alternatives that have been evaluated with the same discount rate, so be sure to perform the same analysis on all alternatives.*

If you are unsure of the validity of the basic data you used to estimate costs, you may want to change your assumptions about one or more of the life-cycle cost categories. In that case, vary costs that represent a significant percentage of your total costs. These generally include construction costs, recurring maintenance costs, costs of major equipment, and recurring leasing costs. Changing upfront costs is going to have a greater effect on your analysis than changing out-year costs. A good rule of thumb in performing a sensitivity analysis is to vary only nonrecurring costs that happen early in the life of an alternative. For recurring items, vary only those that are more than 20 percent of your annual costs.

Sensitivity analyses can also be performed on qualitative evaluations. This can be accomplished by changing the evaluation criteria used or the weights assigned to the criteria. In the latter case, the raw scores of each alternative will be the same, but the *weighted* scores will differ.

The results of the sensitivity analysis must be in the same form as those of the the primary analysis. If the BCR is used to rank alternatives, it must be calculated for each sensitivity analysis performed.

What does a sensitivity analysis that results in a change in ranking indicate? It does not necessarily mean that the initial ranking is not valid. It simply indicates something about the weaknesses in the analysis. No decision should be based on a single factor. The economic analysis process provides a means for evaluating program alternatives. Decisions among alternatives should take into consideration all the information available and be based on what best accomplishes the Air Force mission.

CHECKLIST

STEP 6: PERFORMING SENSITIVITY ANALYSES

	Yes	No
Life-Cycle Costs:		
Are there uncertainties in the cost assumptions for:		
Construction?	☐	☐
Major equipment?	☐	☐
Recurring maintenance?	☐	☐
Major utilities?	☐	☐
Leasing?	☐	☐
Benefits:		
Are there uncertainties in the value of:		
Increased productivity/efficiency?	☐	☐
User savings?	☐	☐
Decreased down time?	☐	☐
Decreased failures or errors?	☐	☐
Other benefits?	☐	☐
Are the life-cycle costs and/or benefits of two or more alternatives within 15% of one another?	☐	☐
Does the ranking of alternatives based on benefits differ from that based on life-cycle costs alone?	☐	☐
Does the ranking of alternatives based on qualitative evaluation factors differ from that based on life-cycle costs?	☐	☐

If the answer to any of the above is YES, a sensitivity analysis should be considered.

STEP 7: DOCUMENTING THE ANALYSIS

The economic analysis report is a key document. The quality of the analysis and the information presented in the documentation can influence whether a project is submitted for funding and, ultimately, whether it receives funding from Congress. The report should be thorough and concise. It should summarize data used, constraints identified, and the conclusions reached. It should include the rationale for all assumptions and explain and justify the decisions made. The report will typically consist of about 10 to 20 pages of narrative, summary forms, and the Certificate of Satisfactory Economic Analysis. It should include Forms S-1, S-2, and S-3 of this manual. The economic analysis does not have to be submitted DD Form 1391c; it may be submitted on plain bond (8-1/2 x 11 inches).

The economic analysis report is forwarded with the final DD Form 1391 submittal. In addition, Block 11 of DD Form 1391 must contain a statement similar to one of the following:

1. All known alternative options were considered during the development of this project. No other option could meet mission requirements; therefore, no economic analysis was needed or performed.
2. An economic analysis has been prepared comparing the alternatives of [specify]. Based on the net present values of the costs and benefits of the respective alternatives, new construction was found to be the most cost efficient over the life of the project.
3. An economic analysis has been prepared on this project. Based on the savings associated with the implementation of the project, it will pay for itself in 7.5 years, with a savings-investment ratio of 1.5.

The economic analysis report should be in the following format:

Cover Sheet

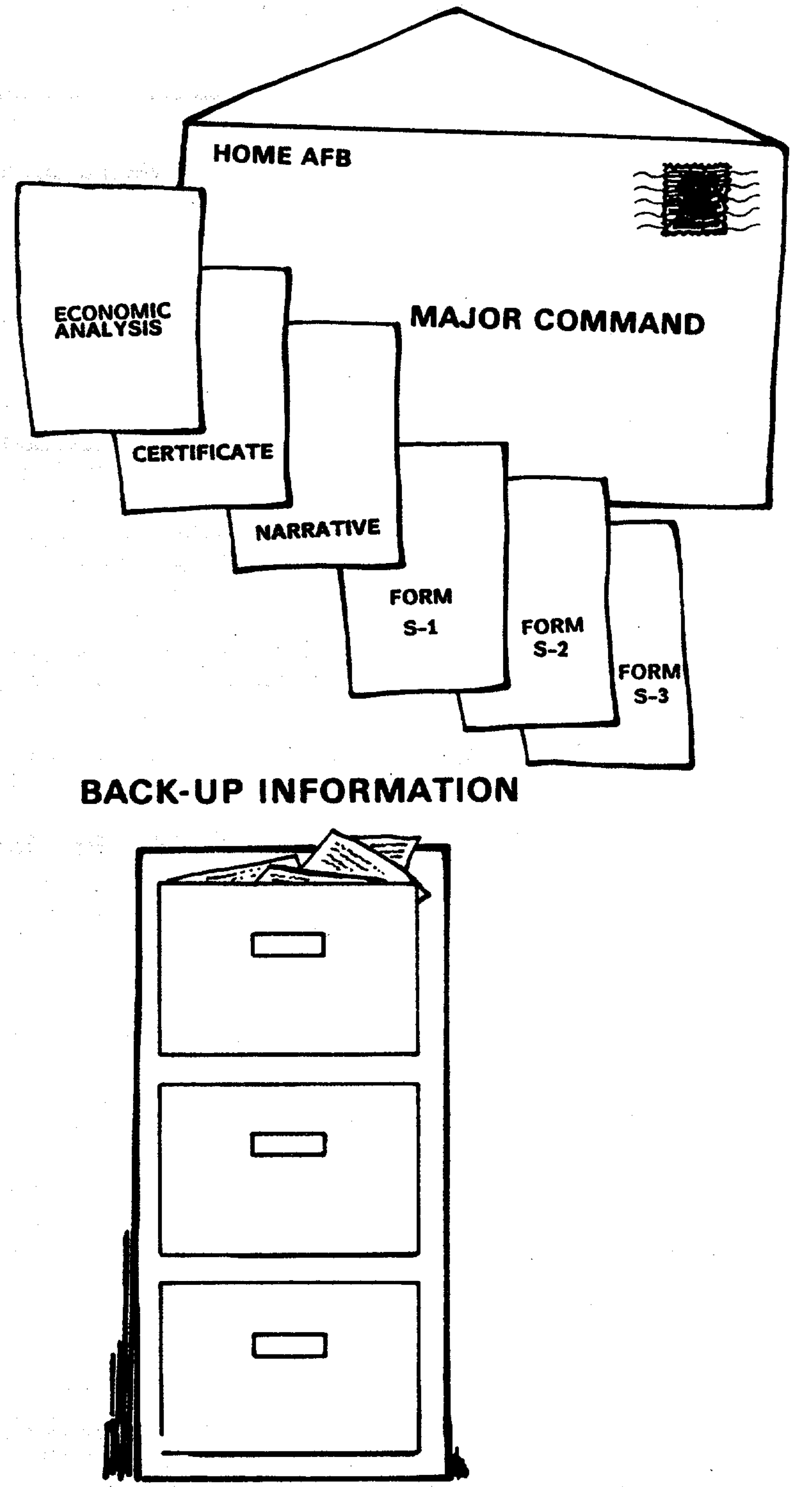
Certificate of Satisfactory Economic Analysis

Table of Contents

1.0 Introduction

1.1 <u>Requirement</u>

Describe the nature of the requirement and the circumstances that led to its identification. Indicate whether a mission change is involved. Also indicate whether the requirement involves structural deficiencies or functional inadequacies.


HOME AFB
MAJOR COMMAND
ECONOMIC ANALYSIS
CERTIFICATE
NARRATIVE
FORM S-1
FORM S-2
FORM S-3
BACK-UP INFORMATION

1.2 Background

Provide a succinct summary of existing conditions, including an overview of past O&M costs, and highlight deficiencies that require correction. Indicate what impact not implementing the proposed project would have on meeting mission requirements. Specify if existing facilities involved are historic. Provide sources of background data used.

1.3 Objectives

Summarize the objectives of the proposed project, indicating which deficiencies would be corrected. These objectives should also be the basis for identifying feasible alternatives and for evaluation criteria used to compare them.

2.0 Alternatives Considered

2.1 Alternatives Evaluated

Describe the alternatives that were evaluated in detail in the economic analysis. Provide a brief summary of each, indicating the number and square footage of facilities involved, the type of work to be done, the life expectancy of the facilities, and other pertinent information. If any of the alternatives involves replacing an existing facility, indicate what will be done with the existing facility. In the discussion, include what disposition options were considered (e.g., demolition, protective storage, or conversion), which was selected and why, and what costs are associated with the selected disposition.

2.2 Alternatives Determined to be Infeasible

Briefly summarize the alternatives initially considered but eliminated as being infeasible or unreasonable. Indicate why.

3.0 Life-Cycle Cost Analysis

3.1 Constraints and Assumptions

Identify constraints encountered in performing the analysis, such as data availability. Discuss assumptions used in the life-cycle costs analyses. Identify data sources.

3.2 Life-Cycle Costs

Discuss the results of the life-cycle cost analysis. Summarize the present values of all alternatives in tabular form. Attach Form S-1 for each alternative.

4.0 Benefits Evaluation

4.1 Constraints and Assumptions

Identify constraints encountered in measuring benefits, especially quantitative benefits. Indicate what assumptions were used to derive any user cost savings and productivity increases. Indicate what quantitative benefits were considered, why they are justified, and how they were measured. Specify qualitative factors considered relevant and describe criteria used to evaluate those factors. Indicate how each qualitative factor used was weighted to reflect relative importance.

4.2 Benefits

Discuss the results of the benefits analysis. Summarize the present values of the quantitative benefits of alternatives. Provide a table of qualitative scores. Attach Form S-2 for each alternative that had a quantitative benefit.

5.0 Comparison of Alternatives

Compare the alternatives with respect to overall performance. Discuss BCR, payback period, SIR, and any other comparative evaluations performed. Include a break-even graph. Discuss each alternative's performance relative to qualitative factors. Provide a table summarizing the relative performance of the alternatives.

Rank all alternatives according to factors considered important to the decision. Indicate the basis of the overall ranking and whether it is based on benefit-cost ratio, return on investment, qualitative factors, or a combination of factors. Attach Form S-3.

6.0 Sensitivity Analysis

Indicate which, if any, sensitivity analyses were conducted and which variables were altered (e.g., changes in cost assumptions or discount rates). Summarize the effect that changing each of these variables had on the alternatives and on the results of the analysis.

7.0 Conclusions and Recommendation

Indicate which alternative was selected and why. In particular, provide justification if the lowest-cost alternative or the alternative with the greatest benefits was not selected.

CHECKLIST

STEP 7: DOCUMENTING THE ANALYSIS

Certificate of Satisfactory Economic Analysis *-1 page*

Table of Contents *-1 page*

1.0 Introduction *-1-2 pages*
Requirement
Background
Objectives

2.0 Alternatives Considered *-1-2 pages*
Alternatives Evaluated
Alternatives Determined To Be Infeasible

3.0 Life-Cycle Cost Analysis *- 3-5 pages*
Constraints and Assumptions
Life-Cycle Costs

4.0 Benefits Analysis *- 1-3 pages*
Constraints and Assumptions
Benefits

5.0 Comparison of Alternatives *-1 page*

6.0 Sensitivity Analysis *-1-2 pages*

7.0 Conclusions and Recommendation *-1-2 paragraphs*

APPENDIX A: GLOSSARY

ALTERNATIVE. Approach or project to meet a need, including current practice. In this manual, alternatives are approaches identified to meet a specified requirement and evaluated in the economic analysis.

BCR. An acronym for benefit-cost ratio. For this analysis, the BCR of an alternative is the total of its quantitative benefits divided by its life-cycle costs. The BCR of the status quo alternative is always 1.

BENEFIT. An objective qualitative or quantitative measure of an action's effectiveness in meeting program objectives or needs. For this analysis, quantitative benefits of an alternative are equal to user savings over the status quo plus the value of any increase in productivity and the life-cycle cost of the status quo (which is assumed to be saved if the alternative is implemented).

BREAK-EVEN POINT. The break-even point between two alternatives is the point at which they are equally cost-effective. It is determined by plotting the alternatives' life-cycle costs on a graph.

BUILD-TO-LEASE. A program for providing government facilities through private-sector development. The government contracts with a private developer to have facilities built, with a guarantee that the government will lease the facilities for a certain period.

BURDENED SALARY. True costs associated with paying personnel, including direct salaries, benefits, employer's share of social security payments, leave and holiday costs, and noncash benefits such as base housing. AFR 173-13 provides guidance on calculating burdened salaries.

CRITERION. For this analysis, a measure of qualitative benefits.

DEFAULT VALUE. A quantitative measure, usually a multiplier, that is built into the analysis process. Examples include interest rates, inflation rates, overhead rates, and O&M costs.

DISCOUNT RATE. The interest rate used to adjust life-cycle costs to reflect the change in the value of capital over time.

ECONOMIC ANALYSIS. A systematic approach to deciding how to use scarce resources based on analyzing and comparing the costs and benefits of alternative approaches to meeting a need.

EPIR. An acronym for efficiency/productivity-investment ratio. For this analysis, the EPIR of an alternative is the total of its quantitative benefits divided by its programmed amount on DD Form 1391.

FACTOR. An area considered important in evaluating an action's qualitative benefits. Criteria are the measurable aspects of factors.

INFLATION. The increase in costs of goods and services over time.

Investment cost. For this analysis, investment cost is equal to the project's programmed amount, which is identified on DD Form 1391.

Life-cycle cost. The total cost of an item over its full useful life. It includes cost of development, procurement, operation, maintenance, and where applicable, disposal.

M&R. An acronym for maintenance and repair. M&R projects refer to such periodic activities as roof and other structural repairs and weather-stripping, as opposed to routine annual maintenance activities.

O&M. An acronym for operations and maintenance. O&M activities and costs are associated with the routine, recurring aspects of keeping up a facility, including utilities, repainting, and replacing worn-out equipment.

Payback period. The time it takes before the difference in life-cycle costs between an alternative and the status quo is equal to the alternative's investment cost; the point at which a project has paid for itself.

Present value. The sum of life-cycle costs in terms of comparable costs in the present, considering inflation and interest rates. For the economic analysis, "present" means the program year used for the analysis.

Program year. The fiscal year for which funding is being requested. For the economic analysis, life-cycle costs are presented in program-year dollars for all options.

Real interest rate. An interest rate with inflation removed, used to determine the real return on investment. For the economic analysis, a 10% rate is used. An alternative rate can be calculated for sensitivity analysis by subtracting current rates of inflation from current interest rates for long-term U.S. Treasury securities.

SIR. An acronym for savings-investment ratio. For this analysis, the SIR is equal to anticipated user cost savings divided by the project's programmed amount, which is on DD Form 1391.

Useful life. The period of time over which benefits are derived from a project. A facility's useful life is the period of time over which it is expected to be usable, with routine maintenance, before improvements or major repairs are required.

APPENDIX B: LIFE-CYCLE COST DATA SOURCES

INTRODUCTION

This appendix provides information on data sources used to complete Worksheets 1 through 6 for the life-cycle cost analysis. It also contains default values for some items that can be used if local data are unavailable.

The appendix is organized by worksheet. Within each worksheet's section, the major cost categories discussed correspond to the cost categories included on the worksheet itself. The items in bold on the worksheet have default values in the appendix. For instance, "Annual Maintenance Cost per Square Foot," which is bold on Worksheet 1, is specifically addressed in this appendix, and default values are provided.

In most cases, it is preferable to use local data, if they are available and reliable. The sections on each worksheet also provide suggested sources of local data. Table B-1 summarizes these data sources; it is only a summary, and the text of this appendix should be consulted for more detail.

Table B-1

SUMMARY OF DATA SOURCES

	Primary Source	*Alternate Source*	*Other Alternatives*
WORKSHEET 1 Annual Maintenance Costs	WIMS - (actual past M&R costs for a particular facility type or building)	DEMRC: Form 1135	BCE: RCS HAF LEE (SA) 7101*
WORKSHEET 2 Periodic Maintenance, Repair, and Replacement Costs	WIMS - (same as above)	DEMRC: Individual facility jackets	Means, Dodge, or other construction cost manuals
WORKSHEET 3 Utility Costs	Base Energy Office, DD Form 1391 (for design energy targets)	BCE: RCS HAF LEE (SA) 7101	Major command consumption report
WORKSHEET 4 Miscellaneous Operations and Maintenance Costs	Base Contracting Office, Facilities Management Office	Means, Dodge, or other construction cost manuals	
WORKSHEET 5 Miscellaneous User Costs	Base Supply Office, Base Transportation Office		
WORKSHEET 6 Lease Costs	Base Real Property Office, Base Billeting Office	Off-base real estate broker	Air Force Accounting and Finance Center, Lowry AFB for TDY data

* Maintenance and repair costs on this form also include the major cost items calculated on Worksheet 2; therefore, Worksheet 2 should not be completed if this data source is used.

WORKSHEET 1: ANNUAL MAINTENANCE COSTS

Annual Maintenance

Annual Maintenance Cost per Square Foot

Annual maintenance is required to maintain facilities in working order. The maintenance requirements vary according to a number of factors, including building age and type and regional area. Annual maintenance does not include the replacement of major building systems, such as the roof, floor, or HVAC, which are addressed on Worksheet 2.

Estimates of maintenance costs are based on a survey of a range of building types at a number of Air Force bases. Table 1-1 provides baseline costs for four types of buildings. These costs must be modified to reflect the base's location. Table 1-2 contains area cost factors by which costs must be multiplied before using on the first line of Worksheet 1. For example, annual maintenance of a warehouse in Phoenix would average $0.48 per square foot (i.e., $0.48 x 0.99 [the area cost factor from Table 1-2]).

Maintenance costs calculated using this method may be more accurate than historical base data. Historical cost data can be hard to work with and are often incomplete. For example, it is difficult at the base level to separate maintenance costs from the total costs of job orders, in-house work orders, contracts, and military construction program (MCP) projects. It is even more difficult to track maintenance costs over time. In addition, some portion of normal maintenance for a building may have been deferred, so that actual cost records would understate the amount necessary to maintain a building in first-rate condition.

Escalation Factor

Building Age Multiplier

The annual maintenance cost per square foot can be adjusted to reflect the age of a facility. Maintenance costs can be escalated over the life of the facility to reflect increased maintenance requirements as the facility ages. Table 1-3 provides building age multipliers that can be used with method 1 on Worksheet 1 to escalate maintenance costs. Note that if the facility is not new, a building age multiplier would be used starting in the first year of the analysis. For example, if the warehouse in Phoenix mentioned above is 15 years old, the annual maintenance cost per square foot would be multiplied by 1.40 (the age multiplier for buildings from 10 to 19 years old) in the first year. In the 6th year of the analysis, the age multiplier would be changed to 1.90 (building 20 to 29 years old) where it would remain until the 16th year, when it would be changed to 2.10, and so on. If reliable local data are available from which an average annual change in maintenance costs can be determined, method 2 can be used to establish an escalation factor.

Table 1-1

ANNUAL MAINTENANCE COSTS

Building Type	*Cost per Square Foot ($)*
Administration/Training	0.60
Maintenance/Production	0.60
Warehouse/Storage	0.48
Dormitory/Community Services	0.57

Source: URS Survey, 1987.

Table 1-2

U.S. AIR FORCE AREA COSTS FACTORS[1]

(page 1 of 2)

Location	*Factor*
Alabama	.83
Birmingham	.92
Huntsville	.88
Mobile	.81
Montgomery	.77
Maxwell AFB	.77
Alaska	2.48
Aleutian Island	3.51
Anchorage	1.81
Delta Junction	2.70
Fairbanks	2.07
Galena	3.37
Clear AFS	2.80
Eielson AFB	2.07
Elmendorf AFB	1.81
Arizona	1.01
Flagstaff	1.04
Phoenix	.99
Tuscon	1.01
Yuma PG	1.21
Arkansas	.91
Fort Smith	.96
Little Rock	.87
Pinebluff	.91
California	1.21
Los Angeles	1.20
San Diego	1.23
San Francisco	1.21
Beale AFB	1.22
Castle AFB	1.10
Edwards AFB	1.25
George AFB	1.23
March AFB	1.24
McClellan AFB	1.16
Norton AFB	1.18
Travis AFB	1.23
Vandenberg AFB	1.28
Colorado	.98
Colorado Springs	.95
Denver	.99
Pueblo	1.01
Peterson AFB	1.02
Connecticut	1.13
Delaware	1.00
Dover AFB	.99
Florida	.87
Cape Kennedy	.93
Gulf Coast Area	.84
Miami	.97
Panama City	.87
Tampa	.78
Homestead AFB	.97
Macdill AFB	.77
Eglin AFB	.84
Tyndall AFB	.87
Georgia	.80
Atlanta	.86
Columbus	.75
Kings Bay	.99
Macon	.75
Hawaii	1.33
Honolulu	1.40
Kona	1.26
Maui	1.26
Hickam AFB	1.40
Wheeler AFB	1.45
Idaho	1.07
Boise	1.05
Idaho Falls	1.05
Mountain Home AFB	1.12
Illinois	1.01
Chicago	1.09
Rock Island	.98
Chanute AFB	1.15
Scott AFB	1.01
Indiana	1.02
Indianapolis	1.05
Grissom AFB	1.08
Iowa	1.02
Kansas	.93
Topeka	.92
Wichita	.92
Kentucky	.95
Louisiana	.90
New Orleans	.95
Shreveport	.89
Barksdale AFB	.89
England AFB	.85
Maine	.95
Bangor	.90
Northern Area	1.17
Portland	.95
Loring AFB	1.01
Maryland	.95
Annapolis	1.04
Baltimore	.93
Andrews AFB	1.04
Massachusetts	1.12
Boston	1.10
Springfield	1.13
Hanscom AFB	1.16
Michigan	1.07
Detroit	1.09
Marquette	1.08
Northern Area	1.25
K.I. Sawyer AFB	1.08
Wurtsmith AFB	1.04
Minnesota	1.14
Duluth	1.13
Minneapolis	1.16
Missippi	.84
Biloxi	.86
Jackson	.82
Columbus AFB	.83
Keesler AFB	.86
Missouri	.94
Kansas City	.95
St. Louis	1.00
Whiteman AFB	1.05
Montana	1.15
Malmstrom AFB	1.15
Nebraska	1.04
Offutt AFB	1.06

Table 1-2

U.S. AIR FORCE AREA COSTS FACTORS[1]

(page 2 of 2)

Location	Factor
Nevada	1.19
Hawthorn	1.30
Las Vegas	1.11
Reno	1.15
Nellis AFB	1.11
New Hampshire	1.08
Concord	1.08
Portsmouth	1.11
New Jersey	1.11
Newark	1.11
Trenton	1.09
McGuire AFB	1.11
New Mexico	1.02
Albuquerque	1.01
Holloman AFB	1.09
Kirtland AFB	1.01
White Sands M.R.	1.09
New York	1.15
Albany	1.08
New York City	1.28
Syracuse	1.09
Ft. Drum	1.18
Griffiss AFB	1.03
Plattsburg AFB	1.18
North Carolina	.78
Greensboro	.77
Wilmington	.80
Pope AFB	.85
Seymour Jn AFB	.78

Location	Factor
North Dakota	1.02
Grand Forks AFB	1.03
Minot AFB	1.05
Ohio	1.04
Columbus	1.04
Youngstown	1.04
Wright-Patterson AFB	1.04
Oklahoma	.90
Oklahoma City	.90
Altus AFB	1.00
Tinker	.88
Oregon	1.03
Pennsylvania	1.01
Philadelphia	1.09
Pittsburg	1.04
Rhode Island	1.09
South Carolina	.82
Columbia	.74
Myrtle Beach	.81
Charleston AFB	.91
Shaw AFB	.78
South Dakota	.98
Sioux Falls	1.00
Ellsworth	.98
Tennessee	.86
Memphis	.95
Arnold AFS	.93

Location	Factor
Texas	.85
San Angelo	.80
San Antonio	.83
El Paso	.96
Carswell AFB	.93
Dyess AFB	.94
Brooks, Randolph, Kelly, & Lackland AFBs	.83
Goodfellow AFB	.80
Laughlin AFB	.91
Utah	1.03
Salt Lake City	1.01
Hill AFB	1.04
Vermont	.96
Virginia	.93
Norfolk	.91
Richmond	.94
Washington	1.16
Spokane	1.14
Tacoma	1.11
Fairchild AFB	1.19
McChord	1.26
Washington, D.C.	1.05
West Virginia	.97
Wisconsin	1.06
Milwaukee	1.08
Wyoming	1.05
F.E. Warren AFB	1.05

1. Factors are normalised to a 144 city average (three cities each in 48 states).

Source: USAF Annual Construction Pricing Guide for FY 1988 to 1992 MCP, October 1986.

Table 1-3

BUILDING AGE MULTIPLIERS

Years	*Multiplier*
0-9	1.00
10-19	1.40
20-29	1.90
30-39	2.10
40-50	2.10
50 plus	1.65

Source: Building Owners Management Association (BOMA) 1985 Income/Expense Survey.

WORKSHEET 2: PERIODIC MAINTENANCE, REPAIR, AND REPLACEMENT COSTS

Periodic costs involve the repair or replacement, at various intervals, of major building subsystems. Listed on Worksheet 2, these include foundations, roofing, interior walls and doors, finishes, ceilings, support systems, and utility systems. Estimates of periodic costs depend on the lifetime of the subsystems and the cost of repair or replacement.

M&R Cost per Square Foot

The cost of replacing a subsystem can be estimated using new construction costs on AF Form 1178. Typically, this form is included in the DD Form 1391 package prepared for every MCP project. Replacement costs can also be estimated using square-foot-based construction cost indexes. The subsystems listed on Worksheet 2 can be used to reference the *Means Square Foot Costs* guide. This source can be used for older buildings for which AF Form 1178 may not have been prepared.

Two adjustments should be made to the subsystem replacement costs before they are entered on Worksheet 2. First, the new cost of a subsystem does not include costs associated with removing an old system before installing a replacement. Research by Biedenweg and Hutson (1981) suggests that the new cost of each subsystem be multiplied by a factor of 1.3 to reflect the total cost of a subsystem replacement. This is a reasonable figure to use if better local base civil engineer (BCE) data are not available. The second adjustment employs the area cost factor to adjust for local price differentials. Area cost factors are listed in Table 1-2.

Life Expectancy

Subsystem lifetimes vary for different regions and, thus, should be estimated based on the experience of the local BCE. In the absence of local data, the estimated life-cycle averages in Table 2-1 can be used.

Table 2-1

LIFE CYCLES OF BUILDING SYSTEMS
(National Average)

Subsystem	*Average Life*[1]
Foundations, floors, structural walls, roof structures, stairs	75 years
Roofing (including coverings, insulation, and specialties)	20 years
Interior walls and doors, windows, exterior closure	50 years
Wall and floor finishes, paint, wall coverings, and carpeting	7 years
Ceiling finishes	20 years
Elevators	40 years
Fire protection equipment	50 years
HVAC	20 years
Plumbing (water and sewer)	40 years
Electrical (including wiring, switches, receptacles, and fixtures	30 years
Special equipment (including appliances, bookcases, and cabinetry)	25 years

1. Assumes regular annual maintenance.

Source: URS Survey, 1987.

WORKSHEET 3: UTILITY COSTS

Energy

Consumption per Square Foot (in thousands of Btus)

All new Air Force facilities and additions and alterations to existing facilities are required to be designed to meet maximum energy consumption criteria set forth in Engineering Technical Letter (ETL) 86-1. These criteria, referred to as energy budget figures or design energy targets, are specified for different types of facilities (e.g., offices, training facilities, storage buildings) and vary across climate zones as defined by the U.S. Department of Energy. Table 3-1 presents the energy budget figures in thousands of British thermal units (Btus) per square foot for each of 16 major facility types by climate zone. The Air Force bases in each climate zone are listed in Table 3-2. The energy budget figures in Table 3-1 distribute total energy consumption among lighting, cooling and ventilation, space heating, and domestic water heating. The assumptions on which the distribution estimates are based are noted in footnotes.

Table 3-1 can be used to estimate energy consumption in economic analyses as follows:

1. STATUS QUO. The status quo alternative involves continued use of an existing facility. In some cases, the existing facility may be metered, and historic energy records can be used to estimate future energy use. On most bases, very few individual buildings are metered, but many facilities have had an energy audit which should be available from the base energy office. The energy audit can be used to estimate future energy consumption in the status quo facility. In some cases, however, the energy audit may not be available, and the energy budget figures in Table 3-1 should be used to estimate annual energy consumption in the existing facility.

2. RENOVATION. Since renovation may be an alternative to new construction, a DD Form 1391 may not be available. In that case, the energy budget figures in Table 3-3 should be used to estimate annual energy consumption for a renovated facility. Consumption should be distributed among energy sources the same way as with new construction. The BCE can assist in the determination of which energy sources would be used for each category of energy use in the renovated facility.

3. NEW CONSTRUCTION. If an economic analysis is to be prepared prior to preparation of a DD Form 1391 for a new construction project, the energy budget figures in Table 3-1 should be used to estimate annual energy consumption in the new facility. If a DD Form 1391 has already been prepared, a design energy target will be identified on the form and should be used in the economic analysis. The design energy target in the DD Form 1391 should be the same as, or very close to, the energy budget figure in Table 3-1.

Table 3-1

U.S. AIR FORCE ENERGY BUDGET FIGURES
(design target for annual energy consumption, excluding process loads, in thousands of Btus per square foot)

(page 1 of 3)

Climate Zone:	1	2	3	4	5	6	7	8	9
Small Offices (<8000 SF)									
Lighting, Cooling, and Ventilation	22.5	22.5	22.5	31.5	24.5	24.5	24.5	28	28
Space Heating	18	18	18	11.3	8.8	8.8	8.8	10	10
Water Heating	4.5	4.5	4.5	2.3	1.8	1.8	1.8	2	2
Large Offices (>8000 SF)									
Lighting, Cooling, and Ventilation	20	20	20	28	24.5	24.5	21	24.5	24.5
Space Heating	16	16	16	10	8.8	8.8	7.5	8.8	8.8
Water Heating	4	4	4	2	1.8	1.8	1.5	1.8	1.8
Hospitals									
Lighting, Cooling, and Ventilation	47.3	47.3	47.3	67.5	52.5	75	75	78.8	82.5
Space Heating	74.3	74.3	74.3	54	42	20	20	21	22
Water Heating	13.5	13.5	13.5	13.5	10.5	5	5	5.3	5.5
Laboratories [1]									
Lighting, Cooling, and Ventilation	18	18	18	29.3	35.8	40	32	36	48
Space Heating	22.5	22.5	22.5	13.5	16.5	7.5	6	6.8	9
Water Heating	4.5	4.5	4.5	2.3	2.8	2.5	2	2.3	3
Dental Clinics									
Lighting, Cooling, and Ventilation	26	26	26	42.3	35.8	40	32	36	48
Space Heating	32.5	32.5	32.5	19.5	16.5	7.5	6	6.8	9
Water Heating	6.5	6.5	6.5	3.3	2.8	2.5	2	2.3	3
Dispensaries									
Lighting, Cooling, and Ventilation	26	26	26	42.3	32.5	36	28	32	44
Space Heating	32.5	32.5	32.5	19.5	15	6.8	5.3	6	8.3
Water Heating	6.5	6.5	6.5	3.3	2.5	2.3	1.8	2	2.8
Prisons [2]									
Lighting, Cooling, and Ventilation	27.5	27.5	25	32.5	29.3	36	32	36	40
Space Heating	22	22	20	12.5	11.3	6.8	6	6.8	7.5
Water Heating	5.5	5.5	5	5	4.5	4.5	4	4.5	5
Training Facilities (>10 Ft Ceilings)									
Lighting, Cooling, and Ventilation	21	19.5	19.5	27	22.5	24.5	24.5	31.5	35
Space Heating	38.5	35.8	35.8	27	22.5	7	7	9	10
Water Heating	10.5	9.8	9.8	6	5	3.5	3.5	4.5	5
Training Facilities (<10 Ft Ceilings)									
Lighting, Cooling, and Ventilation	19.5	18	18	24.8	20.3	24.5	24.5	28	31.5
Space Heating	35.8	33	33	24.8	20.3	7	7	8	9
Water Heating	9.8	9	9	5.5	4.5	3.5	3.5	4	4.5

Table 3-1

U.S. AIR FORCE ENERGY BUDGET FIGURES
(design target for annual energy consumption, excluding process loads, in thousands of Btus per square foot)

(page 2 of 3)

Climate Zone:	1	2	3	4	5	6	7	8	9
Community-Type Facilities (Group 1)									
Lighting, Cooling, and Ventilation	32.5	30	30	35.8	29.3	32	24	28	32
Space Heating	26	24	24	13.8	11.3	6	4.5	5.3	6
Water Heating	6.5	6	6	5.5	4.5	4	3	3.5	4
Community-Type Facilities (Group 2)									
Lighting, Cooling, and Ventilation	32.5	30	30	35.8	29.3	32	28	32	32
Space Heating	26	24	24	13.8	11.3	6	5.3	6	6
Water Heating	6.5	6	6	5.5	4.5	4	3.5	4	4
Community-Type Facilities (Group 3)									
Lighting, Cooling, and Ventilation	27.5	27.5	25	32.5	29.3	36	32	36	36
Space Heating	22	22	20	12.5	11.3	6.8	6	6.8	6.8
Water Heating	5.5	5.5	5	5	4.5	4.5	4	4.5	4.5
Dining Facilities									
Lighting, Cooling, and Ventilation	26	26	26	39	39	41.3	41.3	48.8	48.8
Space Heating	29.3	29.3	29.3	15	15	8.3	8.3	9.8	9.8
Water Heating	9.8	9.8	9.8	6	6	5.5	5.5	6.5	6.5
Clubs									
Lighting, Cooling, and Ventilation	21	19.5	19.5	39	39	42	38.5	45.5	45.5
Space Heating	38.5	35.8	35.8	19.5	19.5	12	11	13	13
Water Heating	10.5	9.8	9.8	6.5	6.5	6	5.5	6.5	6.5
Theaters and Terminals [2]									
Lighting, Cooling, and Ventilation	30	30	27.5	35.8	32.5	40	36	40	40
Space Heating	24	24	22	13.8	12.5	7.5	6.8	7.5	7.5
Water Heating	6	6	5.5	5.5	5	5	4.5	5	5
Auditoriums [2]									
Lighting, Cooling, and Ventilation	27.5	22.5	20	26	22.8	20	20	20	24
Space Heating	22	18	16	10	8.8	3.8	3.8	3.8	4.5
Water Heating	5.5	4.5	4	4	3.5	2.5	2.5	2.5	3
Museums and Memorials [2]									
Lighting, Cooling, and Ventilation	27.5	22.5	20	26	19.5	20	16	16	20
Space Heating	22	18	16	10	7.5	3.8	3	3	3.8
Water Heating	5.5	4.5	4	4	3	2.5	2	2	2.5
Housing [2]									
Lighting, Cooling, and Ventilation	30	27.5	27.5	29.3	26	32	28	40	44
Space Heating	24	22	22	11.3	10	6	5.3	7.5	8.3
Water Heating	6	5.5	5.5	4.5	4	4	3.5	5	5.5

Table 3-1

U.S. AIR FORCE ENERGY BUDGET FIGURES
(design target for annual energy consumption, excluding process loads, in thousands of Btus per square foot)
(page 3 of 3)

Climate Zone:	1	2	3	4	5	6	7	8	9
Storage (Heated and/or Humidity Control)									
Lighting, Cooling, and Ventilation	15.6	13.2	13.2	19.5	15.6	29.4	21	25.2	37.8
Space Heating	48.8	41.3	41.3	30	24	5.3	3.8	4.5	6.8
Water Heating	.7	.6	.6	.5	.4	.4	.3	.3	.5
Cold Storage									
Lighting, Cooling, and Ventilation	69.3	79.2	84.2	84.2	84.2	79.2	69.3	74.3	89.1
Space Heating	0	0	0	0	0	0	0	0	0
Water Heating	.7	.8	.9	.9	.9	.8	.7	.8	.9
Storage (Minimum Heating and Ventilation)									
Lighting, Cooling, and Ventilation	7.2	7.2	7.2	9.8	7.8	12.6	12.6	16.8	16.8
Space Heating	22.5	22.5	22.5	15	12	2.3	2.3	3	3
Water Heating	.3	.3	.3	.3	.2	.2	.2	.2	.2
Industrial Facilities (>10 Ft Ceilings) [3]									
Lighting, Cooling, and Ventilation	38.3	33.8	33.8	42	39	52	44	48	52
Space Heating	34	30	30	21	19.5	9.8	8.3	9	9.8
Water Heating	12.8	11.3	11.3	7	6.5	3.3	2.8	3	3.3
Industrial Facilities (<10 Ft Ceilings) [3]									
Lighting, Cooling, and Ventilation	31.5	29.3	27	33	33	44	40	52	60
Space Heating	28	26	24	16.5	16.5	8.3	7.5	9.8	11.3
Water Heating	10.5	9.8	9	5.5	5.5	2.8	2.5	3.3	3.8
Commissary [4]									
Lighting, Cooling, and Ventilation	34	32	32	45.5	42.3	41.3	41.3	41.3	48.8
Space Heating	38.3	36	36	17.5	16.3	8.3	8.3	8.3	9.8
Water Heating	12.8	12	12	7	6.5	5.5	5.5	5.5	6.5
Instrumentation and Testing Facilities [3]									
Lighting, Cooling, and Ventilation	36	33.8	29.3	39	33	40	32	36	48
Space Heating	32	30	26	19.5	16.5	7.5	6	6.8	9
Water Heating	12	11.3	9.8	6.5	5.5	2.5	2	2.3	3

[1]-Laboratories energy distribution based on the same distribution as Clinics & Dispensaries.

[2]-Prisons, Theaters and Terminals, Auditoriums, Museums and Memorials, and Housing energy distribution based on the same distribution as Community-Type Facilities.

[3]-Industrial and Instrumentation and Testing Facilities energy distribution based on the same distribution as Assembly-Type Facilities.

[4]-Commissary energy distribution based on the same distribution as Dining Facilities.

Source: U.S. Department of the Air Force Headquarters, Engineering Technical Letter 86-1.

Table 3-2

U.S. AIR FORCE BASES AND CORRESPONDING DEPARTMENT OF ENERGY CLIMATE ZONES

Department of Energy Climate Zones								
1	2	3	4	5	6	7	8	9
Eielson	Elemendorf	Ellsworth	Chanute	Andrews	Arnold	Norton	Bergstrom	Altus
King Salmon	Grand Forks	F.E. Warren	Fairchild	Bolling	Beale		Brooks	Barksdale
	K.I. Saywer	Griffiss	Grissom	Cannon	Blytheville		Davis Monthan	Carswell
	Loring	Malmstrom	Hanscom	Dover	Castle		Eglin	Charleston
	Minot	Plattsburgh	Hill	Kirtland	Edwards		England	Columbus
	Shemya	Wurtsmith	Lowry	McChord	George		Hickam	Dyess
			Mt. Home	McConnell	Holloman		Homestead	Goodfellow
			Offutt	McGuire	Langley		Hurlburt	Gunter
			Otis	Scott	Little Rock		Kelly	Keesler
			Pease	Whiteman	March		Lackland	Maxwell
			USAF Academy	Wright-Patterson	Mather		Laughlin	Nellis
					McClellan		Luke	Robins
					Pope		MacDill	Shaw
					Reese		Moody	Sheppard
					Seymour Johnson		Patrick	Tinker
					Travis		Randolph	Vance
					Vandenberg		Tyndall	
							Williams	

Source: U.S. Department of the Air Force Headquarters, Engineering Technical Letter 86-1, 1986.

Design energy targets are not distributed among energy sources, such as electricity, natural gas, fuel oil, coal, propane, or other energy sources. It is important to include that distribution because costs among energy types can vary significantly in an economic analysis. The percentages of the distribution of the energy budget figures in Table 3-1 can be used to break down the design energy target into estimated Btu requirements for lighting; cooling and ventilation; space heating; and domestic water heating in the new facility. The appropriate energy source for each of those items can be based on what is available on base. Lighting, cooling, and ventilation are typically provided by electricity; space heating can be provided by electricity, natural gas, fuel oil, coal, steam, propane, or other sources; and domestic water heating can be provided by electricity, natural gas, fuel oil, propane, or other sources. Check DD Form 1391 or consult the BCE to determine which source would be used for each requirement.

The energy budget figures in Table 3-1 are design targets for new facilities that are designed specifically to cut energy use in government facilities. As ETL 86-1 points out, energy use is significantly higher in older facilities than in those designed using the current Energy Budget Figures. ETL 86-1 states that the Energy Budget Figures used by the Air Force, "represent an energy consumption of 50% less than for similar facilities designed in 1975." Although there is no specific data presented in ETL 86-1 to support this statement, information from the Building Owners Management Association (BOMA) does support the thesis that older buildings use larger amounts of energy than newer facilities. Data in the *1986 BOMA Experience Exchange Report* indicate that buildings 10 years old and older have energy expenses 35% greater than buildings less than 10 years old. Thus, energy budget figures in Table 3-1 can be multiplied by 1.35 for facilities older than 10 years.

Cost Per Thousand Btus

The cost per thousand Btus of energy should be available from the base energy office. These costs may not be in thousands of Btus and therefore must be converted before using on Worksheet 3. Typically, they may be available in cost per kilowatt-hour of electricity, cost per therm or cubic foot of natural gas, cost per thousand gallons of fuel oil, or cost per short ton of coal. Conversion factors should also be available from the base energy office, and, if necessary, assistance can be requested from the energy office to convert these measures to thousands of Btus. If conversion factors are unavailable from the base energy office, alternate conversion factors are provided below:

ELECTRICITY		
1 megawatt-hour (Mwh)	=	3,413 thousand Btus
NATURAL GAS		
1 million cubic feet (mcf)	=	1,031 thousand Btus
COAL		
1 short ton bituminous	=	24,580 thousand Btus
1 short ton anthracite	=	25,400 thousand Btus
1 short ton coke	=	25,380 thousand Btus
FUEL OIL		
1 barrel distillate	=	5,825 thousand Btus
1 barrel residual	=	6,287 thousand Btus
1 barrel reclaimed	=	5,000 thousand Btus
PROPANE GAS		
1,000 gallons	=	91,800 thousand Btus

In the event that no energy cost data is available from sources on the base, the average prices per thousand Btus for various energy products (e.g., electricity, natural gas, coal) are presented in Table 3-3 for ten energy fuel price regions defined by the Department of Energy. *The ten energy fuel price regions are not related to the nine climate zones, discussed previously, which are also defined by the Department of Energy.* The climate zones are differentiated by variations in the annual number of heating- and cooling-degree days, while the energy fuel price regions are differentiated by variations in energy prices in the United States and its territories; the states and territories which comprise each region are also noted in Table 3-3. Note that the prices provided in Table 3-3 are in 1985 dollars and must be inflated to program-year dollars, using the OSD inflation multiplier, prior to using on Worksheet 3.

Water

Annual Water Use per Unit (in thousands of gallons)

Water use among alternatives may vary depending on building size, type of equipment used, and number of personnel. Any significant differences in the amount of water use among alternatives could result in significant differences in life-cycle costs in an economic analysis, depending on the amount of water use and the price of water relative to other cost factors. In most cases, water use estimates based on facility size, equipment, or personnel can be made using historic use data from the base utility office.

For the status quo alternative, the existing facility may be metered, and historic water use records can indicate a trend on which estimates of future water use can be based. If the existing building is metered, historic use records can also serve as

Table 3-3

AVERAGE COST PER THOUSAND BTUs OF ENERGY
($ FY 1985)

	Department of Energy Fuel Price Regions [1]									
	1	2	3	4	5	6	7	8	9	10
Electricity	.02297	.02261	.01823	.01700	.01802	.01716	.01941	.01593	.01819	.00791
Natural Gas	.00516	.00538	.00483	.00431	.00495	.00391	.00403	.00427	.00510	.00545
Coal	.00248	.00202	.00181	.00201	.00192	.00259	.00195	.00116	.00270	.00280
Fuel Oil, Distillate	.00672	.00670	.00647	.00628	.00655	.00604	.00633	.00623	.00600	.00630
Fuel Oil, Residual	.00508	.00500	.00461	.00427	.00358	.00393	.00349	.00331	.00497	.00584
Liquified Petroleum Gas	.00841	.00861	.00832	.00829	.00793	.00671	.00752	.00737	.00771	.00826

[1]-Regions: 1-Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
2-New Jersey, New York, Puerto Rico, and the Virgin Islands.
3-Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia.
4-Alabama, Canal Zone, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.
5-Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin.
6-Arkansas, Louisiana, New Mexico, Oklahoma, and Texas.
7-Iowa, Kansas, Missouri, and Nebraska.
8-Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming.
9-American Samoa, Arizona, California, Guam, Hawaii, Nevada, and the Pacific Islands Territory.
10-Alaska, Idaho, Oregon, and Washington.

[2]-Liquified petroleum gas prices can also be used for propane or butane gas.

Source: U.S. Department of Commerce, Energy Prices and Discount Factors for Life-Cycle Cost Analysis, 1985.

the baseline for estimates of future water use for a renovation alternative. Water use could be assumed to decrease in a renovated facility if water-saving equipment is to be installed. For a new construction alternative, historic use records for a similar new facility can serve as an estimate of future water use in the new building.

If data are not available from individually metered buildings, water use for each alternative can be estimated based on average rates for the base, such as average use for specific appliances or equipment, average use per square foot of building space, or average use per person. Assistance can be requested from the base utility office to derive such average use rates.

When there is insufficient data at the base level to estimate water use rates, the average per person rates in Table 3-4 can be used for each alternative in the economic analysis. These rates include an average rate and a normal range of water use for a person in a one-year period. For example, the average person would use approximately 22,300 gallons of water per year for domestic purposes (at place of residence). This figure could be used for housing and dormitory projects. Commercial and industrial consumption represents use by the average person in the work place. Table 3-4 indicates that the average person uses 29,000 gallons annually in a commercial or industrial setting. This figure could be used for offices, dining facilities, industrial facilities, or any facility with personnel working and using water.

Public use represents use in public areas, such as recreation facilities, clubs, auditoriums, museums, and community facilities. In these type of facilities, it may be necessary to estimate water use for two distinctly different groups of people. For example, users of a recreational facility may use an average of 4,500 gallons annually, while personnel *working* at the facility could be assumed to use water at the commercial/industrial rate of 29,000 gallons annually.

If there is any evidence that water use would be lower or higher than the average provided in Table 3-4, then using another rate that is within the normal range indicated may be more appropriate than the average rate. In that case, the alternative rate must be fully justified and supported with evidence demonstrating that the average rates may not be accurate.

Cost per Thousand Gallons Of Water

The cost of water should be available from the base utility office, either from the utilities engineer or from the water contract monitor. The information should be available in (or converted to) program-year dollars per thousand gallons before using on Worksheet 3. This cost may vary depending on the source of the water. Many bases pump and treat groundwater from on-base well fields, as well as purchase additional water from an off-base water supplier.

Cost of water may vary among alternatives depending on the location of the proposed project (e.g., water on one portion of the base may be supplied by on-base sources at one cost, while water on another portion of the base may be provided by an off-base supplier at another cost; the appropriate cost would therefore depend on the location of the project).

Table 3-4

ANNUAL WATER USE PER PERSON
(in thousands of gallons)

	Average	*Normal Range*	
		Low	*High*
Domestic Use	22.3	4.5	31.2
Commercial/Industrial Use	29.0	4.5	44.6
Public Use	4.5	2.2	8.9
Miscellaneous Use	11.1	4.5	17.8
TOTAL	66.8	15.6	102.5

Source: U.S. Department of the Interior, Geological Survey, Estimated Use of Water in the United States in 1980, 1983; Fair, Geyser, and Okun, Water Supply and Wastewater Removal 1966, as cited in U.S. Department of the Interior, Geological Survey, Western Coal Planning Assistance Project, 1979.

Table 3-5

AVERAGE COST PER THOUSAND GALLONS OF WATER
($ FY 1986)

On-Base Sources	*Off-Base Sources*	*Weighted Average*
0.3180	0.6637	0.4033

Sources: Economic Resources Impact Statements from Dover AFB, Delaware FY 1984 and FY 1985, Norton AFB, California FY 1985, Seymour Johnson AFB, North Carolina FY 1985, Wright-Patterson AFB, Ohio FY 1984 and FY 1985, Ellsworth AFB, South Dakota FY 1985, and Lowry AFB, Colorado FY 1985; RCS HAF-LEE(SA)7101 Civil Engineering Cost Report from Vandenberg AFB, California FY 1986.

On some bases, the on- and off-base water may be blended, in which case a weighted average cost per thousand gallons should be used. The utility office should be able to determine this weighted average cost, if blending is occurring on the base. For off-base lease alternatives, water costs should be available from the local water supplier.

If water costs are unavailable from these sources, the average costs per thousand gallons of water in Table 3-5 may be used. These costs are based on a compilation of water consumption and expenditures at several Air Force bases throughout the continental U.S. as reported in base Economic Resources Impact Statements (ERIS).

Sewage Treatment

Ratio of Sewage Treatment to Water Consumption

The ratio of sewage treatment to water consumption is a function of the total volume of sewage treatment related to the total volume of water consumed on base and should be available from the base utility office. For off-base lease alternatives, this ratio can be computed based on information from the local water and sewage treatment suppliers.

In the event this ratio is unavailable from these sources, an average ratio of 72% (sewage treatment to water use) can be used. This ratio is an engineering standard and is based on the estimated distribution of water consumption shown in the table below, which was computed by the United States Geological Survey (1983).

ESTIMATED DISTRIBUTION OF WATER USE
(in percent)

Return flow (sewage)	72
Consumptive use	23
Conveyance loss	5

Cost Per Thousand Gallons Of Sewage Treatment

The cost of sewage should be available from the base utility office, the utilities engineer, or the contract monitor. The information should be available in, or converted to, dollars per thousand gallons. Just as the cost of water can vary depending on the source of the supply, sewage treatment costs may also vary depending on how treatment is provided. Some bases treat sewage in an on-base plant as well as purchase additional sewage treatment services from off-base facilities.

The cost of treatment for each alternative in the economic analysis may vary depending on the location of the proposed project (i.e., sewage on a portion of the base may flow to an on-base treatment plant at one cost per gallon, but sewage treatment on another portion of the base may be provided by an off-base facility at another cost; the appropriate cost would therefore depend on the location of the project). As with water, a weighted average cost per thousand gallons may be appropriate in some cases. The utility office should be able to determine a weighted average cost if sewage flows to multiple facilities. For off-base lease alternatives, sewage treatment costs should be available from the local sewage treatment provider.

If sewage treatment costs are unavailable from these sources, the average cost per thousand gallons of treatment shown below may be used. These costs are based on a compilation of sewage treatment data from several ERIS reports.

AVERAGE COST PER THOUSAND GALLONS OF SEWAGE TREATMENT
($ FY 1986)

On-Base Treatment	*Off-Base Treatment*	*Weighted Average*
0.3180	0.6637	0.4033

Sources: Economic Resources Impact Statements from Dover AFB, Delaware FY 1984 and FY 1985, Norton AFB, California FY 1985, Seymour Johnson AFB, North Carolina FY 1985, Wright-Patterson AFB, Ohio FY 1984 and FY 1985, Ellsworth AFB, South Dakota FY 1985, and Lowry AFB, Colorado FY 1985; RCS HAF-LEE(SA)7101 Civil Engineering Cost Report from Vandenberg AFB, California FY 1986.

WORKSHEET 4: MISCELLANEOUS OPERATIONS AND MAINTENANCE COSTS

Protective Storage

Initial One-Time Costs

Initial one-time protective storage costs will vary depending on the age, condition, and type of facility that is to be placed in storage. Cost estimates should be made by the BCE. In lieu of this, some basic costs from *Means Repair and Remodeling Cost Data* for potential protective storage activities are shown below:

Item	*Cost ($ FY 1986)*
Board up doors and windows	0.80 per sq ft of opening
Install reinforced plastic on wood framing	1.13 per sq ft of opening
Disconnect utilities	78.00 for each utility

The appropriate area cost factor (Table 1-2) should be applied to these figures.

Annual O&M Cost per Square Foot

Annual operations and maintenance protective storage costs will also vary depending on the age, condition, and type of facility that is vacated. The variation is too great for a meaningful default value. The BCE should provide an estimate of the annual cost of providing the appropriate level of service to maintain the vacated facility.

Trash Removal

Annual Tons Generated

Estimates of the amount of trash generated in existing facilities should be available from the base service contract monitor. For renovated or new facilities, the amount of trash generated can be estimated by extrapolating from existing buildings of similar size, condition, type, and use. The service contract monitor should have data from which extrapolations of costs per square foot or per person can be made.

If trash removal costs for existing buildings are unavailable, the following average annual per-person waste disposal rates for the U.S. can be used.

U.S. AVERAGE ANNUAL WASTE DISPOSAL PER PERSON (in tons)

Domestic	0.205
Commercial, industrial	0.267
Public	0.041
Miscellaneous	0.103
TOTAL	0.615

Source: U.S. Environmental Protection Agency, unpublished data, as cited in the U.S. Department of Commerce, Statistical Abstract of the United States, 1986.

Cost Per Ton for Removal

The cost per ton of trash removed can also be obtained from the service contract monitor. If local data are unavailable, the following average costs may be used.

AVERAGE COST PER TON FOR TRASH REMOVAL ($ FY 1986)

Dump fee	17.00
Transportation and handling	37.87[1]
TOTAL	54.87

1. Transportation and handling costs assume that the distance to dump is approximately 5 miles.

Source: R. S. Means Company, Inc., Means Construction Cost Data, 1987.

The appropriate cost factor (Table 1-2) should be applied to these figures.

Custodial Services

Custodial Cost per Unit

Custodial costs for existing buildings are maintained by the BCE and are available from the chief of Planning and Resources or the Real Property Contracts administrator. If historical custodial costs are reported for a group of buildings, square-foot costs for individual buildings can be estimated by dividing the total cost by the number of square feet in the buildings being maintained. Custodial costs do not change substantially with the renovation of a building, provided that staffing remains constant. Historical costs can also be used to forecast expenditures for new buildings, based on square feet or the number of personnel in the building.

In the absence of historical data, custodial costs can be assumed to be $0.05 (FY 1986 dollars) per square foot of space cleaned. This figure must be multiplied by the number of times per week that the facility is cleaned and the area cost factor (Table 1-2) before using on Worksheet 4.

WORKSHEET 5: MISCELLANEOUS USER COSTS

Transportation

Cost per Mile

Transportation costs among competing development alternatives may vary significantly depending on facility location and the number and type of vehicles used. These variances can be accounted for in an economic analysis by estimating the annual amount of vehicle-miles accumulated for each of the alternatives. These estimates can usually be made by, or in consultation with, the head of the operation(s) which would occupy the new facility.

Once vehicle-mile estimates are made for each of the alternatives, an estimate of the operating cost per mile for each vehicle must be determined. Vehicle operation and maintenance costs are documented by the base transportation office. The Vehicle Integrated Management System (VIMS) records vehicle costs per mile for all Air Force vehicles. This system tracks the actual costs associated with fuel, oil, and maintenance and repair for each vehicle on base and calculates an average cost per mile for each type of vehicle. Other costs, such as the purchase price of vehicles and depreciation, are also included in the cost per mile figure. Table 5-1 provides Air Force-wide average vehicle costs, which can be used if base figures are not available.

Furniture, Fixtures, and Equipment

The replacement costs for real property installed equipment (RPIE) are usually included in the periodic renewal component of maintenance and repair costs. For example, HVAC usually accounts for 15% to 20% of total building costs and is replaced every 20 years, on average. Furniture, fixtures, and equipment costs for new buildings are usually included in the DD Form 1391 project costs. A few items, such as blinds and carpets, may not be included in construction costs and should be estimated individually using method 2 on Worksheet 5. The *Mean's Building Construction Cost Data 1987* has a large section on equipment and furnishings. Costs of furniture and non-RPIE equipment are usually not included in the original construction estimates and should also be estimated individually.

Table 5-1

U.S. AIR FORCE AVERAGE MOTOR VEHICLE COST PER MILE (\$ FY 1984)

	Total Cost (\$)[1]	*Total Miles*	*Cost per Mile (\$)*
Automobiles, Sedan	11,384,111	42,476,441	0.26801
Station Wagons	3,717,197	15,456,763	0.24049
Ambulances	1,818,149	2,888,977	0.62934
Buses, >15 Passenger	9,557,385	14,580,075	0.65551
4x2 Trucks, <8,500 lbs.	70,664,298	196,218,860	0.36013
4x4 Trucks, <8,500 lbs.	15,218,157	37,366,261	0.40727
Trucks, 8,501 - 23,999 lbs.	8,357,442	13,471,054	0.62040
Trucks, <24,000 lbs.	9,076,651	12,882,905	0.70455

1. Total cost includes fuel, maintenance, depreciation, and indirect costs.

Source: U.S. General Services Administration, Federal Motor Fleet Report, 1985.

WORKSHEET 6: LEASE COSTS

Lease

Annual Lease Cost per Square Foot

Lease costs can vary considerably depending on the building type, the length and type of lease, and the location of the leased facility. Lease costs can be very important factors in an economic analysis and, therefore, local data should be used whenever possible. The base real estate property office or a local real estate broker can provide an accurate estimate of prospective lease costs. According to the U.S. General Services Administration *Summary Report of Real Property Leased to the United States Throughout the World* (1984), the average cost of building space leased by the U.S. Air Force is $4.43 per square foot (FY 1983 dollars). This average cost is presented only as a rough estimate and does not distinguish between types of buildings, types of leases, or location.

Temporary Quarters

Data on temporary quarters, including on-base and contract quarters, can be obtained from the base billeting office. Costs of off-base quarters used by personnel issued nonavailability certificates are equivalent to current housing and per diem rates for the base's location. These can be obtained from the base accounting and finance office (travel pay).

FORM S-1: CAPITAL INVESTMENT

Capital investment costs are usually available from DD Form 1391 for a proposed action, but determining the capital investment for alternatives considered in the economic analysis may require additional calculations. If an alternative involves new construction, the same steps followed in completing AF Form 1178 should be used to determine the amount of investment for the economic analysis. If an alternative involves renovation, capital costs can be estimated using either the *Air Force Pricing Guide* or *Means Square Foot Costs.* Costs estimated solely from the *Means Square Foot Costs* guide are typically lower because they do not include many items such as renovating or replacing supporting facilities or equipment, which are included in the *Air Force Pricing Guide* cost estimates.

Since cost estimates based only on *Means Square Foot Costs* data can underestimate actual renovation costs, it is preferable to combine construction costs from the *Air Force Pricing Guide* with the percentage distribution of costs among building components or subsystems from *Means Square Foot Costs* to derive the capital investment required for a renovation project. For example, a renovation project is planned that will replace the doors, windows, and finishes of an existing office building but none of the structural elements. The *Air Force Pricing Guide* estimates the cost of constructing a new facility to be $100 per square foot. *Means Square Foot Costs* distributes construction costs for office buildings among subsystems as follows:

Foundations, floors, and structures	19%
Roofing	2%
Interior walls, doors, and windows	13%
Wall and floor finishes	18%
Ceiling finishes	8%
Elevators	5%
Fire protection equipment	1%
HVAC	18%
Plumbing	2%
Electrical	14%

Since the renovation project involves replacing doors, windows, and finishes, only 39% of the full construction cost would be required, based on *Means Square Foot Costs* (13% + 18% + 8%). Thus, the $100 per square foot would be multiplied by 39% to obtain the estimated cost of renovation ($39 per square foot). Note that *Means Square Foot Costs* distributes costs by dollars, not by percentages. The percentages must be derived by dividing the subsystem cost by the total cost estimated in *Means Square Foot Costs.*

The estimated square-foot cost must then be escalated by a demolition/removal factor and an area cost factor. The cost of demolition or removal is estimated by Biedenweg and Hutson (1981) at 30% of the cost of construction. Thus, the total cost of removing an old subsystem and installing a new one equals the estimated cost of new construction times 130%. This factor is only a rough rule of thumb and should be modified on the advice of local construction experts. Area cost factors are provided in Table 1-3.

APPENDIX C: ECONOMIC ANALYSIS MULTIPLIERS

Table C-1

OSD INFLATION INDEX

Fiscal Year	*Index*
1982-83*	1.049
1983-84*	1.038
1984-85	1.037
1985-86	1.044
1986-87	1.042
1987-88	1.040
1988-89	1.037
1989-90 on (annual)	1.034

To use these indices over more than one year, multiply the first applicable index by the next index, then by the following index in sequence until the desired year is reached. For example, to calculate inflation between 1983 annd 1987, multiply the index for 1983-84 (1.038) by the index for 1984-85 (1.037), then by the index for 1985-86 (1.044), and finally by the index for 1986-87 (1.042). The equation would be as follows:

$$1.038 \times 1.037 = 1.076 \times 1.044 = 1.123 \times 1.042 = 1.171$$

Source: AFR 173-13. Updated index may be obtained from HQ USAF/ACC/LEEP or the local ACC Office.

* **Actual inflation rates as measured by the Department of Commerce, Bureau of Economic Analysis.**

Table C-2

PRESENT VALUE MULTIPLIERS

	Discount Rate									
Year	*5%*	*6%*	*7%*	*8%*	*9%*	*11%*	*12%*	*13%*	*14%*	*15%*
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1	0.952	0.943	0.935	0.926	0.917	0.901	0.893	0.885	0.877	0.870
2	0.907	0.890	0.873	0.857	0.842	0.812	0.797	0.783	0.769	0.756
3	0.864	0.840	0.816	0.794	0.772	0.731	0.712	0.693	0.675	0.658
4	0.823	0.792	0.763	0.735	0.708	0.659	0.636	0.613	0.592	0.572
5	0.784	0.747	0.713	0.681	0.650	0.593	0.567	0.543	0.519	0.497
6	0.746	0.705	0.666	0.630	0.596	0.535	0.507	0.480	0.456	0.432
7	0.711	0.665	0.623	0.583	0.547	0.482	0.452	0.425	0.400	0.376
8	0.677	0.627	0.582	0.540	0.502	0.434	0.404	0.376	0.351	0.327
9	0.645	0.592	0.544	0.500	0.460	0.391	0.361	0.333	0.308	0.284
10	0.614	0.558	0.508	0.463	0.422	0.352	0.322	0.295	0.270	0.247
11	0.585	0.527	0.475	0.429	0.388	0.317	0.287	0.261	0.237	0.215
12	0.557	0.497	0.444	0.397	0.356	0.286	0.257	0.231	0.208	0.187
13	0.530	0.469	0.415	0.368	0.326	0.258	0.229	0.204	0.182	0.163
14	0.505	0.442	0.388	0.340	0.299	0.232	0.205	0.181	0.160	0.141
15	0.481	0.417	0.362	0.315	0.275	0.209	0.183	0.160	0.140	0.123
16	0.458	0.394	0.339	0.292	0.252	0.188	0.163	0.141	0.123	0.107
17	0.436	0.371	0.317	0.270	0.231	0.170	0.146	0.125	0.108	0.093
18	0.416	0.350	0.296	0.250	0.212	0.153	0.130	0.111	0.095	0.081
19	0.396	0.331	0.277	0.232	0.194	0.138	0.116	0.098	0.083	0.070
20	0.377	0.312	0.258	0.215	0.178	0.124	0.104	0.087	0.073	0.061
21	0.359	0.294	0.242	0.199	0.164	0.112	0.093	0.077	0.064	0.053
22	0.342	0.278	0.226	0.184	0.150	0.101	0.083	0.068	0.056	0.046
23	0.326	0.262	0.211	0.170	0.138	0.091	0.074	0.060	0.049	0.040
24	0.310	0.247	0.197	0.158	0.126	0.082	0.066	0.053	0.043	0.035
25	0.295	0.233	0.184	0.146	0.116	0.074	0.059	0.047	0.038	0.030
26	0.281	0.220	0.172	0.135	0.106	0.066	0.053	0.042	0.033	0.026
27	0.268	0.207	0.161	0.125	0.098	0.060	0.047	0.037	0.029	0.023
28	0.255	0.196	0.150	0.116	0.090	0.054	0.042	0.033	0.026	0.020
29	0.243	0.185	0.141	0.107	0.082	0.048	0.037	0.029	0.022	0.017
30	0.231	0.174	0.131	0.099	0.075	0.044	0.033	0.026	0.020	0.015
31	0.220	0.164	0.123	0.092	0.069	0.039	0.030	0.023	0.017	0.013
32	0.210	0.155	0.115	0.085	0.063	0.035	0.027	0.020	0.015	0.011
33	0.200	0.146	0.107	0.079	0.058	0.032	0.024	0.018	0.013	0.010
34	0.190	0.138	0.100	0.073	0.053	0.029	0.021	0.016	0.012	0.009
35	0.181	0.130	0.094	0.068	0.049	0.026	0.019	0.014	0.010	0.008
36	0.173	0.123	0.088	0.063	0.045	0.023	0.017	0.012	0.009	0.007
37	0.164	0.116	0.082	0.058	0.041	0.021	0.015	0.011	0.008	0.006
38	0.157	0.109	0.076	0.054	0.038	0.019	0.013	0.010	0.007	0.005
39	0.149	0.103	0.071	0.050	0.035	0.017	0.012	0.009	0.006	0.004
40	0.142	0.097	0.067	0.046	0.032	0.015	0.011	0.008	0.005	0.004
41	0.135	0.092	0.062	0.043	0.029	0.014	0.010	0.007	0.005	0.003
42	0.129	0.087	0.058	0.039	0.027	0.012	0.009	0.006	0.004	0.003
43	0.123	0.082	0.055	0.037	0.025	0.011	0.008	0.005	0.004	0.002
44	0.117	0.077	0.051	0.034	0.023	0.010	0.007	0.005	0.003	0.002
45	0.111	0.073	0.048	0.031	0.021	0.009	0.006	0.004	0.003	0.002
46	0.106	0.069	0.044	0.029	0.019	0.008	0.005	0.004	0.002	0.002
47	0.101	0.065	0.042	0.027	0.017	0.007	0.005	0.003	0.002	0.001
48	0.096	0.061	0.039	0.025	0.016	0.007	0.004	0.003	0.002	0.001
49	0.092	0.058	0.036	0.023	0.015	0.006	0.004	0.003	0.002	0.001
50	0.087	0.054	0.034	0.021	0.013	0.005	0.003	0.002	0.001	0.001

APPENDIX D: QUALITATIVE EVALUATION CRITERIA

AVAILABILITY/ACCESSIBILITY. The extent to which a service or facility is available for personnel use can be determined by the location of a service or recreation facility relative to its customers. It can also be influenced by the adequacy of a facility to perform the service (e.g., adequate space and equipment to provide hot meals) or to serve the number of potential users (e.g., adequate number of racquetball courts).

EFFICIENCY. Efficiency is similar to productivity, except that it assumes that total output remains the same while the resources needed to produce the output decrease. Benefits of increased efficiency should be quantified whenever possible in terms of cost savings.

ENVIRONMENTAL IMPACT. This criterion is generally used when the status quo is causing pollution or otherwise damaging the environment and a project is being considered to correct the problem. It may also be used if any of the alternatives being considered is likely to have environmental effects.

HEALTH/SAFETY. The benefits of a healthy and safe working or living environment are usually not quantifiable in dollars. An alternative that results in the removal of hazardous materials or correction of an unsafe condition is providing a benefit that should be considered in the evaluation. This criterion also covers improvements in fire protection.

HISTORIC PRESERVATION. This criterion is used if the existing facility or a facility considered in one of the alternatives is historic and likely to be altered or demolished. An historic facility is one which is on or qualifies to be on the National Register of Historic Places. Historic preservation may also be a consideration if archaeological resources may be affected by a proposed project.

LAND USE COMPATIBILITY. Functions that are adjacent to one another may not always be compatible. Appropriate land uses are generally defined in the base comprehensive plan. A facility that operates on waivers is often incompatible with its location. In that case, a replacement facility programmed for a different site may provide a benefit by eliminating the incompatibility and therefore the requirement for waivers. In another case, a proposed new site may be less compatible than a function's existing location.

MAINTAINABILITY/SERVICEABILITY. Modernizing a facility can make it easier to maintain the facility or service its equipment. This benefit may not be quantifiable but can be expected to improve overall base civil engineering efficiency.

Not intended to represent an exhaustive list of qualitative evaluation criteria. Others may also be used if appropriate. Not all criteria may be applicable for all economic analyses.

MORALE. Morale is important both to performance and to retention of Air Force personnel. This criterion applies primarily to recreation, housing, community services, and similar projects, although an adequate working environment can also improve morale.

OFF-BASE EFFECTS. Off-base socioeconomic effects may be a consideration if a substantial increase in assigned personnel is anticipated. The criterion can also be used if an alternative under consideration for the base would result in either an increase or decrease in dollars spent in the local community.

PRODUCTIVITY. Productivity is the level of output of a function or organization, given its resources. If possible, productivity should be quantified in terms of output. Although it is not always possible to quantify increases in productivity, they can often be expected with an alternative. Productivity can be evaluated qualitatively; if, for instance, current conditions are substandard or inadequate and personnel are not working at their potential, an alternative designed to improve facilities would likely result in increased output. Productivity is distinct from efficiency.

RELIABILITY/ACCURACY/ACCEPTABILITY. These criteria measure the extent to which a function meets its performance expectations. Reliability most often refers to the extent to which one can count on equipment performing to expectations (e.g., new equipment may be more reliable than old). Accuracy refers to reliability of information, such as accurate measurement (e.g., a new Precision Measurement Equipment Laboratory may increase the accuracy of measurements performed). Acceptability usually refers to personnel performance (e.g., personnel working in an adequate facility are more likely to do acceptable work).

SECURITY. Security refers to the ability of a facility to protect the resources it houses. Security requirements differ depending on the function performed and are often specified in Air Force regulations. If physical security is inadequate, additional security personnel may be required to compensate for the shortcoming. If this requirement can be quantified, it should be included in the life-cycle cost analysis (Worksheet 5). Key personnel, as well as physical assets, can require security.

APPENDIX E: WORKSHEET AND FORMS

Contents

Worksheet 1:	Annual Maintenance Costs
Worksheet 2:	Periodic Maintenance, Repair, and Replacement Costs
Worksheet 3:	Utility Costs
Worksheet 4:	Miscellaneous Operations and Maintenance Costs
Worksheet 5:	Miscellaneous User Costs
Worksheet 6:	Lease Costs
Worksheet 7:	Quantitative Benefits
Worksheet 8:	Qualitative Benefits

Form S-1:	Total Life-Cycle Costs
Form S-1a:	Total Life-Cycle Costs (sensitivity analysis)
Form S-2:	Total Life-Cycle Benefits
Form S-2a:	Total Life Cycle Benefits (sensitivity analysis)
Form S-3:	Ranking of Alternatives

WORKSHEET 1
Annual Maintenance Costs
(In Program-Year Dollars)
Alternative: ____________________

Annual Maintenance

Annual Maintenance Cost per Square Foot		________
Number of Square Feet of Building Space	(X)	________
Total Annual Maintenance Cost	(=)	________

Escalation Factor (Method 1 - Building Age Multiplier)

Year of Construction or Renovation of Facility:	________	
Building Age Multiplier During Years:	________	________
Building Age Multiplier During Years:	________	________
Building Age Multiplier During Years:	________	________
Building Age Multiplier During Years:	________	________
Building Age Multiplier During Years:	________	________

Escalation Factor (Method 2 - Average Annual Change)

Year of Construction or Renovation of Facility:	________	
Average Annual Change in Maintenance Costs During Years:	________	________%
Average Annual Change in Maintenance Costs During Years:	________	________%
Average Annual Change in Maintenance Costs During Years:	________	________%
Average Annual Change in Maintenance Costs During Years:	________	________%
Average Annual Change in Maintenance Costs During Years:	________	________%

Assumptions, Additional Calculations, and Data Sources:

____

____

____

____

WORKSHEET 2

Periodic Maintenance, Repair, and Replacement Costs

(In Program-Year Dollars)

Alternative: ____________________

Foundations, Floors, Structural Walls, Roof Structures, Stairs

M&R Cost per Square Foot ____________
Number of Square Feet of ________ Space (X)____________
Subtotal M&R Cost (=)____________
Life Expectancy: ________ Years
Years M&R Would Be Required ______________________________

Roofing

M&R Cost per Square Foot ____________
Number of Square Feet of ________ Space (X)____________
Subtotal M&R Cost (=)____________
Life Expectancy: ________ Years
Years M&R Would Be Required ______________________________

Interior Walls and Doors, Windows, Exterior Closure

M&R Cost per Square Foot ____________
Number of Square Feet of ________ Space (X)____________
Subtotal M&R Cost (=)____________
Life Expectancy: ________ Years
Years M&R Would Be Required ______________________________

Wall and Floor Finishes, Paint, Wall Coverings, Carpeting

M&R Cost per Square Foot ____________
Number of Square Feet of ________ Space (X)____________
Subtotal M&R Cost (=)____________
Life Expectancy: ________ Years
Years M&R Would Be Required ______________________________

Ceiling Finishes

M&R Cost per Square Foot ____________
Number of Square Feet of ________ Space (X)____________
Subtotal M&R Cost (=)____________
Life Expectancy: ________ Years
Years M&R Would Be Required ______________________________

Elevators

M&R Cost per Square Foot ____________
Number of Square Feet of ________ Space (X)____________
Subtotal M&R Cost (=)____________
Life Expectancy: ________ Years
Years M&R Would Be Required ______________________________

WORKSHEET 2

Periodic Maintenance, Repair, and Replacement Costs

(In Program-Year Dollars)

Alternative: ____________________

Fire Protection Equipment

M&R Cost per Square Foot ____________

Number of Square Feet of ________ Space (X)____________

Subtotal M&R Cost (=)____________

Life Expectancy: ________ Years

Years M&R Would Be Required ______________________________

HVAC

M&R Cost per Square Foot ____________

Number of Square Feet of ________ Space (X)____________

Subtotal M&R Cost (=)____________

Life Expectancy: ________ Years

Years M&R Would Be Required ______________________________

Plumbing

M&R Cost per Square Foot ____________

Number of Square Feet of ________ Space (X)____________

Subtotal M&R Cost (=)____________

Life Expectancy: ________ Years

Years M&R Would Be Required ______________________________

Electrical

M&R Cost per Square Foot ____________

Number of Square Feet of ________ Space (X)____________

Subtotal M&R Cost (=)____________

Life Expectancy: ________ Years

Years M&R Would Be Required ______________________________

Special Equipment

M&R Cost per Square Foot ____________

Number of Square Feet of ________ Space (X)____________

Subtotal M&R Cost (=)____________

Life Expectancy: ________ Years

Years M&R Would Be Required ______________________________

Assumptions, Additional Calculations, and Data Sources:

____

____

____

____

WORKSHEET 3
Utility Costs
(In Program-Year Dollars)
Alternative: ____________________

Electricity

Consumption per Square Foot (in thousands of Btus)	______
Number of Square Feet of Building Space	(X)______
Annual Electricity Consumption (in thousands of Btus)	(=)______
Cost per Thousand Btus	(X)______
Total Annual Electricity Cost	(=)______

Natural Gas

Consumption per Square Foot (in thousands of Btus)	______
Number of Square Feet of Building Space	(X)______
Annual Natural Gas Consumption (in thousands of Btus)	(=)______
Cost per Thousand Btus	(X)______
Total Annual Natural Gas Cost	(=)______

Coal

Consumption per Square Foot (in thousands of Btus)	______
Number of Square Feet of Building Space	(X)______
Annual Coal Consumption (in thousands of Btus)	(=)______
Cost per Thousand Btus	(X)______
Total Annual Coal Cost	(=)______

Fuel Oil

Consumption per Square Foot (in thousands of Btus)	______
Number of Square Feet of Building Space	(X)______
Annual Fuel Oil Consumption (in thousands of Btus)	(=)______
Cost per Thousand Btus	(X)______
Total Annual Coal Cost	(=)______

Propane Gas

Consumption per Square Foot (in thousands of Btus)	______
Number of Square Feet of Building Space	(X)______
Annual Propane Gas Consumption (in thousands of Btus)	(=)______
Cost per Thousand Btus	(X)______
Total Annual Propane Gas Cost	(=)______

Other Energy Products (____________________)

Consumption Per Square Foot (in thousands of Btus)	______
Number of Square Feet of Building Space	(X)______
Annual Consumption (in thousands of Btus)	(=)______
Cost per Thousand Btus	(X)______
Total Annual Cost	(=)______

WORKSHEET 3

Utility Costs

(In Program-Year Dollars)

Alternative: ____________________

Water

Number of Units (e.g., square feet, personnel, equipment)	______________
Annual Water Use per Unit (in thousands of gallons)	(X)______________
Total Annual Water Use	(=)______________
Cost per Thousand Gallons of Water	(X)______________
Total Annual Water Cost	(=)______________

Sewage Treatment

Total Annual Water Use (from water calculations above)	______________
Ratio of Sewage Treatment to Water Use	(X)______________
Total Annual Sewage Treatment	(=)______________
Cost per Thousand Gallons of Sewage Treatment	(X)______________
Total Annual Sewage Treatment Cost	(=)______________

TOTAL ANNUAL UTILITY COST	(=)______________

Assumptions, Additional Calculations, and Data Sources:

____

____

____

____

WORKSHEET 4 (OPTIONAL)
Miscellaneous Operations and Maintenance Costs
(In Program-Year Dollars)
Alternative: ____________________

Protective Storage

Initial One-Time Costs		
Board Up Doors and Windows		________
Disconnect Utilities	(+)	________
Minor Repair	(+)	________
Other ____________	(+)	________
Total One-Time Cost	(=)	________
Annual O&M Costs		
Annual O&M Cost per Square Foot		________
Number of Square Feet	(X)	________
Total Annual Cost	(=)	________

Trash Removal

Annual Tons Generated per Unit (e.g., square feet, personnel)		________
Cost per Ton For Removal	(X)	________
Annual Cost per Unit	(=)	________
Number of Units	(X)	________
Total Annual Cost	(=)	________

Custodial Services

Number of Units (e.g., rooms, offices, or square feet)		________
Custodial Cost per Unit	(X)	________
Subtotal Annual Cost	(=)	________
Other Fixed Costs (costs not based on the number of units)	(+)	________
Total Annual Cost	(=)	________

Grounds Maintenance

Annual Cost per Square Foot		________
Number of Square Feet	(X)	________
Subtotal Annual Cost	(=)	________
Other Fixed Costs (costs not based on the number of units)	(+)	________
Total Annual Cost	(=)	________

Assumptions, Additional Calculations, and Data Sources:

WORKSHEET 5 (OPTIONAL)
Miscellaneous User Costs
(In Program-Year Dollars)
Alternative: ____________________

Transportation

Annual Amount of Vehicle or Equipment Use (in miles or hours)		______
Cost per Mile or Hour	(X)	______
Total Annual Cost	(=)	______

Furniture, Fixtures and Equipment (Method 1 - Average Cost per Unit)

Number of Units (e.g., rooms, offices or personnel)		______
Annual Furniture, Fixtures and Equipment Cost per Unit	(X)	______
Total Annual Cost	(=)	______

Furniture, Fixtures and Equipment (Method 2 - Itemized Costs)

Items Required	Life Expectancy	Years Required	Cost
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______
______	____ Years	______	______

Other (____________________)

Number of Units (e.g., rooms, offices, or personnel)		______
Cost per Unit	(X)	______
Subtotal Annual Cost	(=)	______
Other Fixed Costs (costs not based on the number of units)	(+)	______
Total Annual Cost	(=)	______

Assumptions, Additional Calculations, and Data Sources:

____
____
____
____

WORKSHEET 6
Lease Costs
(In Program-Year Dollars)
Alternative: ____________________

Lease

Annual Lease Cost per Square Foot *	____________
Number of Square Feet	(X)____________
Total Annual Cost	(=)____________

Temporary Quarters

On Base

Number of Personnel Housed in On Base Quarters per Year	____________
Average Room Rate Plus per Diem	(X)____________
Total Annual Cost **	(=)____________

Contract Quarters

Number of Personnel Housed in Contract Quarters per Year	____________
Average Room Rate Plus per Diem	(X)____________
Total Annual Cost **	(=)____________

Other Quarters (personnel issued nonavailablity certificates)

Number of Personnel Housed in Other Quarters per Year	____________
Average Room Rate Plus per Diem	(X)____________
Total Annual Cost **	(=)____________

* If the Annual Cost per Square Foot is the gross lease cost, then maintenance and repair, custodial services, and utilities costs can be assumed to be included in the price of the lease; if the Annual Cost Per Square Foot is the triple-net lease then maintenance and repair, custodial services, and utilities costs must be estimated separately on the appropriate cost forms.

** Any transportation costs (car rental, pickup service, etc.) should be included in the Transportation cost category on Worksheet 5.

Assumptions, Additional Calculations, and Data Sources:

____

____

____

____

WORKSHEET 7 (OPTIONAL)
Quantitative Benefits
(In Program-Year Dollars)
Alternative: ____________________

<u>Increase in Productivity</u>		
Annual Labor Cost of Alternative		______________
Annual Output of Alternative	(/)	______________
Average Labor Cost per Unit of Output of Alternative	(=)	______________
Annual Labor Cost of Status Quo		______________
Annual Output of Status Quo	(/)	______________
Average Labor Cost per Unit of Output of Status Quo	(=)	______________
Average Labor Cost per Unit of Output of Alternative (from above)	(-)	______________
Average Labor Cost per Unit of Increased Output	(=)	______________
Annual Output of Alternative (from above)	(X)	______________
Total Annual Benefit from Increase in Productivity	(=)	______________
<u>Personnel Cost Savings</u>		
Number of Personnel Affected		______________
Annual Labor Savings per Person Over Status Quo (in hours)	(X)	______________
Total Annual Labor Savings (in hours)	(=)	______________
Average Hourly Burdened Rate of Pay	(X)	______________
Total Annual Benefit From Personnel Cost Savings	(=)	______________
<u>Fuel Cost Savings</u>		
Annual Reduction in Equipment or Vehicle Use (in miles or hours)		______________
Average Fuel Consumption per Mile or Hour (in gallons)	(X)	______________
Total Annual Fuel Savings (in gallons)	(=)	______________
Price per Gallon	(X)	______________
Total Annual Benefit From Fuel Cost Savings	(=)	______________
<u>Other Cost Savings</u>		
Number of Units Receiving Other Savings		______________
Annual Savings per Unit Over Status Quo (in ________________)	(X)	______________
Total Annual Savings (in ________________)	(=)	______________
Price per ______________	(X)	______________
Total Annual Benefit From Other Cost Savings	(=)	______________

Assumptions, Additional Calculations, and Data Sources:

____

____

____

____

WORKSHEET 8 (OPTIONAL)
Qualitative Benefits
Alternative: ____________________

Criteria (Specify)	Score	Weight	Weighted Score
		Total	

Assumptions and Data Sources:

FORM S-1
Total Life-Cycle Costs
Alternative: ____________________

Fiscal Year	(1) Annual Maintenance (Worksheet 1)	(2) Periodic M&R (Worksheet 2)	(3) Utilities (Worksheet 3)	(4) Misc. O&M (Worksheet 4)	(5) Misc. User (Worksheet 5)	(6) Lease (Worksheet 6)	(7) Total Sum (1)-(6)	(8) Present Value Mult. (10% Disc.)	(9) Present Value (7) x (8)	(10) Cumulative Present Value (Annual Sum)
*19__							*	1.000		
**19__								.909		
								.826		
								.751		
								.683		
								.621		
								.564		
								.513		
								.467		
								.424		
								.386		
								.350		
								.319		
								.290		
								.263		
								.239		
								.218		
								.198		
								.180		
								.164		
								.149		
								.135		
								.123		
								.112		
								.102		
								.092		

* Program year; include capital investment in first row of Column (7).

** First year of occupancy.

FORM S-1

Total Life-Cycle Costs

Alternative: ____________________

Fiscal Year	(1) Annual Maintenance (Worksheet 1)	(2) Periodic M&R (Worksheet 2)	(3) Utilities (Worksheet 3)	(4) Misc. O&M (Worksheet 4)	(5) Misc. User (Worksheet 5)	(6) Lease (Worksheet 6)	(7) Total Sum (1)-(6)	(8) Present Value Mult. (10% Disc.)	(9) Present Value (7) x (8)	(10) Cumulative Present Value (Annual Sum)
								.084		
								.076		
								.069		
								.063		
								.057		
								.052		
								.047		
								.043		
								.039		
								.036		
								.032		
								.029		
								.027		
								.024		
								.022		
								.020		
								.018		
								.017		
								.015		
								.014		
								.012		
								.011		
								.010		
								.009		
								.009		
Total										

(page 2 of 2)

FORM S-1a

Total Life-Cycle Costs

Alternative: ____________________

Fiscal Year	(1) Annual Maintenance (Worksheet 1)	(2) Periodic M&R (Worksheet 2)	(3) Utilities (Worksheet 3)	(4) Misc. O&M (Worksheet 4)	(5) Misc. User (Worksheet 5)	(6) Lease (Worksheet 6)	(7) Total Sum (1)-(6)	(8) Present Value Mult. (__% Disc.)	(9) Present Value (7) x (8)	(10) Cumulative Present Value (Annual Sum)
*19__							________*	1.000		
**19__										

* Program year; include capital investment in first row of Column (7).

** First year of occupancy.

(page 1 of 2)

FORM S-1a

Total Life-Cycle Costs

Alternative: ____________________

Fiscal Year	(1) Annual Maintenance (Worksheet 1)	(2) Periodic M&R (Worksheet 2)	(3) Utilities (Worksheet 3)	(4) Misc. O&M (Worksheet 4)	(5) Misc. User (Worksheet 5)	(6) Lease (Worksheet 6)	(7) Total Sum (1)-(6)	(8) Present Value Mult. (___% Disc.)	(9) Present Value (7) x (8)	(10) Cumulative Present Value (Annual Sum)
Total										

(page 2 of 2)

FORM S-2

Total Life-Cycle Benefits

Alternative: ____________________

Fiscal Year	(1) Increased Productivity (Worksheet 7)	(2) Personnel Cost Savings (Worksheet 7)	(3) Fuel Cost Savings (Worksheet 7)	(4) Other Cost Savings (Worksheet 7)	(5) Total Sum (1)-(4)	(6) Present Value Mult. (10% Disc.)	(7) Present Value (5) x (6)	(8) Cumulative Present Value (Annual Sum)
**19__						.909		
						.826		
						.751		
						.683		
						.621		
						.564		
						.513		
						.467		
						.424		
						.386		
						.350		
						.319		
						.290		
						.263		
						.239		
						.218		
						.198		
						.180		
						.164		
						.149		
						.135		
						.123		
						.112		
						.102		
						.092		

** First year of occupancy.

FORM S-2

Total Life-Cycle Benefits

Alternative: ____________________

Fiscal Year	(1) Increased Productivity (Worksheet 7)	(2) Personnel Cost Savings (Worksheet 7)	(3) Fuel Cost Savings (Worksheet 7)	(4) Other Cost Savings (Worksheet 7)	(5) Total Sum (1)-(4)	(6) Present Value Mult. (10% Disc.)	(7) Present Value (5) x (6)	(8) Cumulative Present Value (Annual Sum)
						.084		
						.076		
						.069		
						.063		
						.057		
						.052		
						.047		
						.043		
						.039		
						.036		
						.032		
						.029		
						.027		
						.024		
						.022		
						.020		
						.018		
						.017		
						.015		
						.014		
						.012		
						.011		
						.010		
						.009		
						.009		
Total								

(page 2 of 2)

FORM S-2a

Total Life-Cycle Benefits

Alternative: ____________________

Fiscal Year	(1) Increased Productivity (Worksheet 7)	(2) Personnel Cost Savings (Worksheet 7)	(3) Fuel Cost Savings (Worksheet 7)	(4) Other Cost Savings (Worksheet 7)	(5) Total Sum (1)-(4)	(6) Present Value Mult. (__% Disc.)	(7) Present Value (5) x (6)	(8) Cumulative Present Value (Annual Sum)
**19__								

** First year of occupancy.

FORM S-2a

Total Life-Cycle Benefits

Alternative: ____________________

Fiscal Year	(1) Increased Productivity (Worksheet 7)	(2) Personnel Cost Savings (Worksheet 7)	(3) Fuel Cost Savings (Worksheet 7)	(4) Other Cost Savings (Worksheet 7)	(5) Total Sum (1)-(4)	(6) Present Value Mult. (__% Disc.)	(7) Present Value (5) x (6)	(8) Cumulative Present Value (Annual Sum)
Total								

FORM S-3

Ranking Alternatives

	Status Quo	Alternative: ______	Alternative: ______	Alternative: ______	Alternative: ______	Alternative: ______
Life-Cycle Benefits (from FORM S-2)	N/A	______	______	______	______	______
Life-Cycle Costs of Status Quo (from FORM S-1)	N/A	(+)______	(+)______	(+)______	(+)______	(+)______
Total Life-Cycle Benefit (including Status Quo cost avoidance)	N/A	(=)______	(=)______	(=)______	(=)______	(=)______
Total Life-Cycle Costs (from FORM S-1)	N/A	(/)______	(/)______	(/)______	(/)______	(/)______
Benefit-Cost Ratio (BCR) *	1	(=)______	(=)______	(=)______	(=)______	(=)______
Payback Period (if applicable)	N/A	______	______	______	______	______
Savings-Investment Ratio (SIR)	N/A	______	______	______	______	______
Eff/Prod-Investment Ratio (EPIR)	N/A	______	______	______	______	______
Qualitative Benefit Score	______	______	______	______	______	______
Rank	______	______	______	______	______	______

* If BCR > 1, then that alternative is **more cost-effective** than the status quo.
If BCR < 1, then that alternative is **less cost-effective** than the status quo.
The alternative with the largest BCR is the **most cost-effective** alternative.

INTERNAL DISTRIBUTION

1. T. D. Anderson
2. S. I. Auerbach
3. D. J. Bjornstad
4. R. B. Braid, Jr.
5. M. A. Broders
6. R. S. Burns
7. R. A. Cantor
8. J. B. Cannon
9. S. A. Carnes
10. E. D. Copenhaver
11. R. B. Craig
12. T. R. Curlee
13. S. Das
14. H. B. Davidson
15. R. M. Davis
16. L. D. Eyman
17. C. S. Fore
18. W. Fulkerson
19. S. G. Hildebrand
20. E. A. Hirst
21. R. B. Honea
22. D. B. Hunsaker
23. C. R. Kerley
24. J. M. Kraemer
25. J. R. Merriman
26. D. C. Parzyck
27. E. B. Peele
28. L. W. Rickert
29. R. D. Roop
30. T. H. Row
31. M. Schweitzer
32. R. B. Shelton
33. D. H. Stitt
34. D. P. Vogt
35. T. J. Wilbanks

36-37. Central Research Library
38-39. Document Reference Section
40-60. HAZWRAP Library
61-62. Laboratory Records Department
63-64. Laboratory Records Department—C
65. ORNL Patent Section

EXTERNAL DISTRIBUTION

66. R. Brandin, URS Corporation, 1421 Chapala Street, Santa Barbara, CA 93101
67. C. Clayton, URS Corporation, 1421 Chapala Street, Santa Barbara, CA 93101
68. E. Dunlap, URS Corporation, 1421 Chapala Street, Santa Barbara, CA 93101
69. W. L. Ellersieck, URS Corporation, 1421 Chapala Street, Santa Barbara, CA 93101

70-71. R. Gregory, U.S. Air Force, HQ AFESC/DEC, Tyndall AFB, FL 32403-6001

72. D. S. Jansing, U.S. Air Force, 3750 ABG/DE, Sheppard AFB, TX 76311
73. W. A. Nixon, U.S. Air Force, HQ AFESC/DEMB, Tyndall AFB, FL 32403-6001
74. L. Owens, URS Corporation, 1421 Chapala Street, Santa Barbara, CA 93101

75-84. P. A. Parker, U.S. Air Force, HQ USAF/LEEPR, Pentagon, Room 5D376, Washington, DC 20330-5130

85. Major K. L. Small, U.S. Air Force, HQ USAF/LEEV, Bolling AFB, Washington, DC 20332

EXTERNAL DISTRIBUTION (Continued)

86. R. D. Thomson, URS Corporation, 1421 Chapala Street, Santa Barbara, CA 93101
87. R. E. Van Tassel, URS Corporation, 1421 Chapala Street, Santa Barbara, CA 93101
88. Office of Assistant Manager for Energy Research and Development, U.S. Department of Energy, Oak Ridge Operations Office, P.O. Box E, Oak Ridge, TN 37831

89-90. Office of Scientific and Technical Information, U.S. Department of Energy, P.O. Box 62, Oak Ridge, TN 37831

91-316. U.S. Air Force Headquarters/LEH, Pentagon, Room 5D431, Washington, DC 2033-5130

☆ U.S. GOVERNMENT PRINTING OFFICE 1987—548-118/60116