U.S. Department of Commerce
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Washington, D.C. 20234

NBSIR 80-2040

Recommended Practice for Measuring Life-Cycle Costs of Buildings and Building Systems

Rosalie T. Ruegg
Stephen R. Petersen
Harold E. Marshall

June 1980

NBSIR 80-2040

RECOMMENDED PRACTICE FOR MEASURING LIFE-CYCLE COSTS OF BUILDINGS AND BUILDING SYSTEMS

Rosalie T. Ruegg
Stephen R. Petersen
Harold E. Marshall

Building Economics and Regulatory
Technology Division
Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

June 1980

U.S. DEPARTMENT OF COMMERCE, Philip M. Klutznick, *Secretary*
Luther H. Hodges, Jr., *Deputy Secretary*
Jordan J. Baruch, *Assistant Secretary for Productivity, Technology, and Innovation*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

PREFACE

Life-cycle cost (LCC) analysis, when applied to building decisions, provides an economic evaluation of the net dollar effect, over time, of purchasing, constructing/installing, maintaining, operating, repairing, and replacing buildings or building systems. Rising prices of labor, material, and particularly energy have forced builders, architects, engineers, building owners and operators, and code writers to turn to LCC analysis to identify building designs and building systems that will be cost effective in the long run. A practical, standardized approach for evaluating the LCC of building decisions is needed for widespread acceptance, understandability, and comparability of the results of LCC analysis. Reflecting this need in the public sector, the National Energy Conservation Policy Act of 1978 and an earlier Executive Order by President Carter mandated that a practical and uniform set of LCC methods and procedures be established and used by all Federal agencies in making decisions about energy projects in Federal buildings. A comparable set of guidelines which includes the treatment of taxes and other effects influencing building decisions in the private sector would further promote sound investment decisions as well as aid in the transfer of information among the many parties that together comprise the building community.

This National Bureau of Standards report has been prepared in response to an ongoing standards development activity in the American Society of Testing and Materials (ASTM E-6 -- Performance of Building Constructions) and in response to requests from the building community for assistance in applying life-cycle cost analysis in a uniform and practicable manner. This document has been submitted to ASTM E-6.81, the Building Economics Subcommittee, for its consideration in the development of a "recommended practice for measuring the total life-cycle costs of buildings and building systems." The technical material is presented in such a manner that the Subcommittee can use it to develop either a single or several recommended practices or standards.

This report describes how to measure the total life-cycle costs of an investment. Its preparation is one of a series of steps towards developing a comprehensive set of standard recommended economic practices that will meet the diverse needs of the building community for measures of economic performance. Specifically, this report provides the technical base for the development of a standard method or recommended practice for measuring total life-cycle costs of investments in buildings and building systems. Applying standardized LCC methods to building investment decisions will help to assure that the cost effectiveness of alternative building projects can be compared in a consistent and technically correct manner. This will assist the building community in making cost-effective building investments.

The members of ASTM who attended the Building Economics Subcommittee meeting in October 1979 in Champaign-Urbana agreed upon the basic elements that should be included in an initial life-cycle cost recommended practice. That meeting helped determine the framework of this paper, and therefore special thanks are due those ASTM attendees, including Raymond Albrecht, Donald Carr, Susan Christmas, Earl Ferguson, Selwyn Fox, J. Heslip, David Jeanes, Morris Lieff, Frederick Pneuman, George Ratliff, John Ryan, Jerry Severson, John Smith, and Christopher Tyson.

Thanks are also due our colleagues at the National Bureau of Standards who assisted in the preparation of this report. Special appreciation is extended to James Gross for his reviews and guidance in this project, to Stephen Roberts for his work on the sample investment problem, and to Wayne Stiefel, Charles Mahaffey, and Barry Jackson for their excellent reviews of earlier drafts. Appreciation is also due Mary Ramsburg who typed the manuscript.

ABSTRACT

Rising prices of labor, material, and particularly energy have forced builders, architects, engineers, building owners and operators, and code writers to identify building designs and building systems that will be cost effective in the long run. This report describes how to measure the life-cycle costs of buildings and building systems. Life-cycle cost analysis, when applied to building investment decisions, provides an economic evaluation of the net dollar effect, over time, of purchasing, constructing/installing, maintaining, operating, repairing, and replacing buildings or building systems. This recommended practice for making life-cycle cost evaluations will assist the private and public building communities in making cost-effective decisions.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The term "life-cycle costing" (LCC) encompasses several techniques of economic evaluation which are similar to the extent that they provide a measure of economic performance of an investment over some period of time extending into the future. These techniques differ primarily in their units of measure--dollars, percent, and ratio--and, to some extent, in their applicability to particular types of problems. One of these techniques, referred to herein as the total life-cycle cost (TLCC) technique, means the summing, in either present value or annual value dollars, of all relevant costs associated with an investment or project during an appropriate time period. The TLCC technique is the focus of this recommended practice.

Other LCC techniques, which are closely related to the TLCC technique, are the net benefits technique, which provides a dollar measure of an investment's net profitability; the benefit/cost or savings-to-investment ratio technique, which indicates by a numerical ratio the size of the gross dollar return relative to the size of the investment; and the internal-rate-of-return technique, which gives the percentage yield from an investment. Another related technique which measures economic performance over time is the payback technique, which gives the time required for an investment to recover its costs. These other LCC techniques will be the focus of later efforts to develop a comprehensive package of recommended practices for economic analysis.

1.1 SCOPE AND ORGANIZATION

This report establishes a technical base for the development of a recommended practice for evaluating the total life-cycle costs (TLCC) of buildings and building systems. The TLCC technique measures in present value or annual value dollars the total of all relevant costs associated with an investment decision.

Following a section on relevant definitions, a brief overview of the life-cycle costing (LCC) concept and specific LCC techniques is given in part 1 for perspective. In parts 2 through 6, the procedures for using the TLCC technique are described step by step. The major categories of costs typically treated in a TLCC evalution are identified. Major assumptions required for measuring TLCC are listed and guidelines for making assumptions and selecting parametric values to be used in the measurement are suggested. The "discounting" technique for converting costs and savings spread over time to their equivalent values at a common time is described and equations for calculating TLCC are provided. Following the procedures for performing TLCC analysis, part 7 describes potential applications of the TLCC technique, as well as its limitations. Part 8 identifies the information that should be included in a report of a TLCC analysis. In support of applying the technique, appendix A gives discount factors for making present value and annual value calculations. Appendix B lists a computer program for performing TLCC calculations to further facilitate the use of this technique. This same appendix gives an example of the use of the computer program to solve a building investment problem. Appendix C gives another example of TLCC evaluation--this one solved step-by-step manually with the solution displayed in tabular form. References on LCC analysis are listed in appendix D.

1.2 DEFINITIONS

The following are definitions of common terms relating to LCC analysis.

(1) Annually Recurring Costs - Those costs which are incurred each year in an equal amount or in an amount that is increasing at a constant rate throughout the study period.

(2) Annual Value (Worth) - Project costs or benefits expressed as an equivalent uniform annual amount, taking into account the time value of money.

(3) Annuity - see "Annual Value."

(4) Base Period - The time to which all future and past costs are converted when a present value method is used, usually the beginning of the study period (time zero).

(5) Benefit-Cost Analysis - A method of evaluating projects or investments by comparing the discounted present value or annual value of total expected costs and benefits.

(6) Benefit-Cost Ratio (B/C) - Benefits expressed as a proportion of costs, where both are discounted to a present or annual value. The ratio must be greater than one for an investment to be economically justified on the basis of dollar measurable benefits and costs.

(7) Cash Flow - The stream of dollar values--costs and benefits--resulting from a project or investment. Cash flow analysis accounts for both dollar amounts and their time of occurrence.

(8) Constant Dollars - Values expressed in terms of the purchasing power of the dollar at a given time, usually the base period; i.e., constant dollars do not reflect price inflation.

(9) Cost Effective - Estimated benefits (savings) from an investment project are equal to or exceed the costs of the investment, where both are assessed over the life of the project and discounted to reflect the time value of money.

(10) Current Dollars - Values expressed in terms of the actual prices of each year; i.e., current dollars reflect inflation.

(11) Differential Cost - The difference in an item of cost or in the total cost of two alternatives.

(12) Differential Price Escalation Rate - The expected difference between a general rate of inflation and the rate of increase assumed for a given item of cost, such as energy.

(13) Discount Factor - A multiplicative number, calculated from a discount formula for a given discount rate and interest period, used to convert costs and benefits occurring at different times to a common basis.

(14) Discount Rate - The rate of interest reflecting the investor's time value of money, used in discount formulas or to select discount factors for converting benefits and costs occurring at different times to a common time.

(15) Discounted Payback Period (DPB) - The time required for the cumulative benefits from an investment to pay back the investment cost and other accrued costs, considering the time value of money.

(16) Discounting - A technique for converting cash flows that occur over time to equivalent amounts at a common point in time.

(17) Economic Life - That period of time over which an investment is considered to be the least-cost alternative for meeting a particular objective.

(18) First Cost - The sum of the planning, design, and construction costs necessary to provide a finished building or building component ready for use, sometimes called initial investment cost.

(19) Future Value (Worth) - The value of a dollar amount at some point in the future, considering the time value of money.

(20) Inflation - A rise in the general price level, or, put another way, a decline in the general purchasing power of the dollar.

(21) Internal Rate of Return (IRR) - The compound rate of interest which, when used to discount the life-cycle costs and benefits of a project, will cause the two to be equal.

(22) Initial Investment Cost - The sum of the planning, design, and construction costs necessary to provide a finished building ready for use, sometimes called first cost.

(23) Life Cycle - The period of time between the starting point and cutoff date for analysis, over which the costs and benefits of a certain alternative are incurred, sometimes called the study period or time horizon.

(24) Life-Cycle Costing (LCC) - A general method of economic evaluation which considers all relevant costs associated with an activity or project during its time horizon, comprising the techniques of total life-cycle cost, net savings, internal rate of return, and savings-to-investment or benefit/cost ratio analysis.

(25) Maintenance and Repair Cost - The total of labor, material, transportation, and other related costs incurred in conducting corrective and preventative maintenance and repair on a building and/or its systems, components, and equipment.

(26) Net Benefits (NB) - The difference between the benefits and the costs--evaluated in present or annual value dollars--of a project, activity, or design alternative.

(27) Net Present Value of Investment-Related Costs - The present value of the initial investment costs, plus the present value of replacement costs, less the present value of salvage.

(28) Net Savings (NS) - The difference between the savings and the costs--evaluated in present or annual value dollars--of a project, activity, or design alternative.

(29) Nominal Discount Rate - The rate of interest reflecting the time value of money stemming both from inflation and the real earning power of money over time. This is the discount rate to use in discount formulas or to select discount factors when future benefits and costs are expressed in current (i.e., inflated) dollars.

(30) Non-Annually Recurring Costs - Those costs which do not occur each year in an equal amount nor in an amount that increases at a constant rate throughout the study period.

(31) Operating Costs - The expenses incurred during the normal operating of a building or a building system, component, or equipment, including costs of labor, materials, and utilities.

(32) Opportunity Cost of Capital - The rate of return available on the next best available investment, indicative of the appropriate value of the discount rate.

(33) Present Value (Worth) - The value of a benefit or cost at the present time (i.e., as of the base period), found by discounting future cash flows to the present.

(34) Present Value (Worth) Factor - The discount factor by which a future value may be multiplied to find its value at the present time.

(35) Real Discount Rate - The rate of interest reflecting the real earning power of money over time. This is the discount rate to use in discount formulas or to select discount factors when future benefits and costs are expressed in constant dollars.

(36) Replacement Cost - Any significant future component replacement, included in the capital budget, which is expected to be incurred during the study period in order to maintain the investment at a functional level.

(37) Resale Value - The net sum to be realized from disposal or sale of an asset at the end of its economic life, at the end of the study period, or whenever it is no longer to be used.

(38) Salvage Value - For the purpose of calculating depreciation expenses, the value estimated to remain at the end of the depreciation period.

(39) Savings-to-Investment Ratio (SIR) - Either the ratio of present value savings to present value investment costs, or the ratio of annual value savings to annual value investment costs.

(40) Sensitivity Analysis - Testing the outcome of an evaluation by altering the value of one or more parameters from the initially assumed value(s).

(41) Simple Payback Period (SPB) - A measure of the length of time required for the cumulative benefits, net of cumulative future costs, from an investment to pay back the initial investment cost, without taking into account the time value of money.

(42) Study Period - The length of time over which an investment is analyzed, sometimes referred to as the time horizon or life cycle.

(43) Sunk Cost - A cost which has already been incurred and should not be considered in making a subsequent investment decision.

(44) Time Horizon - The length of time over which an investment is analyzed, sometimes referred to as the study period or life cycle.

(45) Time Value of Money - The time-dependent value of money that may stem both from changes in the purchasing power of money (i.e., inflation or deflation), and from the real earning potential of alternative investments over time. The time value of money is indicated by the rate of interest which will cause the value of a dollar received at some future time to be equivalent in value, from the standpoint of the investor, to a dollar received today.

(46) Total Life-Cycle Costs (TLCC) - A technique of life-cycle costing which finds the sum of the costs of the initial investment (less salvage value), replacements, operations including energy use, and maintenance and repair, over the life-cycle of an investment, expressed in present or annual value dollars.

(47) Useful Life - The period over which an investment continues to generate benefits or savings.

1.3 THE LIFE-CYCLE COST METHOD AND EVALUATION TECHNIQUES

The basic premise of the LCC method is that to an investor or decision maker all costs arising from an investment decision are potentially important to that decision, including future as well as present costs. The LCC method applied to buildings, building systems, and building practices results in an economic evaluation that encompasses the net effect, over time, of purchasing, constructing/installing, maintaining, operating, repairing, and replacing buildings or building systems. This method is referred to herein as the LCC method. (1-8)[1]

A number of alternative economic evaluation techniques exist. Those techniques which are consistent with the LCC method are referred to as LCC techniques. LCC techniques are more comprehensive in their coverage than are economic evaluation techniques which do not encompass all relevant costs over time, and, therefore, conceptually provide the more accurate measures of economic performance. LCC techniques include the Total Life-Cycle Cost (TLCC) Technique (the focus of this report and of the ASTM's initial recommended practice for LCC analysis), the Net Benefits or Net Savings (NB or NS) Technique, the Benefit/Cost or Savings-to-Investment Ratio (B/C or SIR) Technique, and the Internal-Rate-of-Return (IRR) Technique.

---

[1] Numbers in the parentheses refer to the list of references appended to this report.

Related techniques are the Discounted Payback (DPB) and Simple Payback (SPB) Techniques. These two techniques are not fully consistent with the LCC concept because they evaluate costs--or partial costs in the case of Simple Payback--over a time period limited to the time required to recover investment costs, which may be shorter than the time relevant to the investor or decision maker.

1.4 PROCEDURES FOR TOTAL LIFE-CYCLE COST (TLCC) EVALUATION: AN OVERVIEW

The recommended procedures for measuring the TLCC of a building or building system can be summarized in five basic steps as follows:

1. Identify Objective, Alternatives, and Constraints
2. Establish Basic Assumptions
3. Compile Data
4. Discount All Cash Flows to a Comparable Time Basis
5. Compute TLCC's and Compare Alternatives

In the following sections 2 through 6, each of these steps is addressed further.

2. IDENTIFY OBJECTIVE, ALTERNATIVES, AND CONSTRAINTS

First, establish the specific objective of the investor or decision maker, identify alternative ways of accomplishing that objective, and bring out any constraints that limit the available options to be considered. This sets the framework for the TLCC analysis.

An example of a building-related objective that might be addressed by TLCC analysis is the objective of reducing the total costs of the interior furnishings of a building over its useful life. Examples of constraints in meeting this objective are that neither the functional use of the building can be altered nor the productivity of its occupants lowered. For instance, if a certain level of illumination is required, all alternative lighting systems should provide the required level of illumination. General examples of potential ways of accomplishing the cost-reduction objective are to change the quality of the furnishings, to change the maintenance on the furnishings, or to change the length of time the furnishings are kept in service.

3. ESTABLISH BASIC ASSUMPTIONS

Second, set the basic assumptions that are to be followed in applying the TLCC technique to the investment problem at hand. Assumptions usually include, among other things, the time period over which the evaluation is to be made, the value of the discount rate, and the level of comprehensiveness of the TLCC evaluation.

3.1 TIME HORIZON

The selection of a time horizon, the study period over which an investment is analyzed, depends on the personal time perspective of the building investor. It may be much shorter than either the economic life or useful life of the building investment. While there are generally no fixed time horizons for investment projects, the following general guidelines can be given for selecting a time horizon:

(1) When analyzing an investment from the standpoint of determining the economically efficient decision for society, a relatively long time horizon, close or equal to the useful life of the investment, is recommended.

(2) When analyzing an investment from the standpoint of predicting the investment decision that a certain type or group of investors might make--the view a marketing researcher, for instance, might take--an estimate of the "subject's" time horizon is recommended.

(3) When analyzing an investment from a personal or individual investor's standpoint, the use of the specific investor's time horizon is recommended. For a speculative investor, the time horizon might be based on the holding period that is expected to maximize speculative profits. For a homeowner, the time horizon for house-related investments might equal the remaining life of the mortgage, the length of expected occupancy, or the time until resale. For a non-speculative business, the time horizon for an investment in an owner-occupied building might be the economic or useful life of the building or building system, and for an investment property, the time horizon might be selected on the basis of the depreciation period, the financing period, or the intended holding period. For investments by government agencies and large corporations, specific guidelines often direct the choice of time horizons.

(4) Regardless of the type of investor or purpose of the analysis, a general guideline for selecting a time horizon when calculating the present value of all costs associated with an investment is to use the same time horizon for each cost category.

(5) Furthermore, when comparing investment alternatives on the basis of their TLCC's in present value dollars, the same time horizon must be used for each investment alternative.

3.2 DISCOUNT RATE

The discount rate is selected to reflect the investor's time value of money. The discount rate is used to convert costs occurring at different times to a common time. The discount rate should reflect the rate of interest which makes the investor indifferent between paying or receiving a dollar now or at some future time. Discount rates may be expressed in "nominal" (market) terms, where both the effects of inflation and the real earning power of money invested over time are reflected, or in "real" terms, where only the real earning power of money is reflected and inflation is not included.

As in the case of time horizons, there is no single correct discount rate for all investors. However, again some general guidelines can be given:

(1) The discount rate should be selected to reflect the investor's particular time preference for money (5,9). This appropriate rate may be guided by the level of return on alternative investment opportunities, on the cost of borrowing money, or, in the case of public organizations, on mandated or legislated requirements. The earning rate available on alternative investments should take precedence over the borrowing rate as an indicator of the appropriate discount rate if that earning rate exceeds the borrowing rate.

(2) A nominal discount rate should be selected if estimates of future costs and benefits include inflation.

(3) A real discount rate should be selected if estimates of future costs and benefits do not include inflation.

3.3 LEVEL OF COMPREHENSIVENESS

A TLCC evaluation is usually performed to one of three levels of comprehensiveness: Before taxes and before inflation (BTBI), after taxes and before inflation (ATBI), and after taxes and after inflation (ATAI) (6). The level of comprehensiveness selected for a TLCC evaluation depends chiefly on (1) the degree of complexity of the problem, (2) the intended purpose of the evaluation, (3) the level of monetary and non-monetary impacts contingent on the investment decision, (4) the cost of the evaluation, and (5) the evaluation resources available to the investor or decision maker.

Following are some general guidelines for establishing when to undertake an economic evaluation and the level of comprehensiveness for the evaluation:

(1) When costs of investment, operation, repair, and replacement are negligible, and there are expectations of savings, project cost effectiveness can generally be presumed without a formal economic evaluation.

(2) For a government or non-profit investment, a BTBI evaluation will usually suffice. (The BTBI approach does not preclude the inclusion of differential price escalation rates to adjust for price changes faster or slower than general price inflation).

(3) For a private investment subject to taxes, either an ATBI or an ATAI evaluation is usually recommended. If significant items of cost are anticipated to be fixed in amount or to rise at a rate faster or slower than general price inflation, the ATAI evaluation is recommended.

4. COMPILE DATA

4.1 DATA REQUIREMENTS

Third, compile the basic data required to measure the TLCC of the potential alternatives for meeting the objective. For measuring the TLCC of an alternative building design, building system, or building practice, typical cost categories for which data will be needed are investment costs, including the costs of planning, design, engineering, construction, purchase, installation, and financing; non-fuel operating and maintenance costs, including the materials and labor costs for routine upkeep and operation other than energy; repair and replacement costs, including future costs to repair or replace a building system or component thereof which wears out; energy costs; and property and capital gains taxes. Data will also be needed for any cost-reducing items, such as resale values, tax deductible expenses, tax credits, and grants or other subsidies (10,11). Other data requirements are for tax rates, depreciation methods and periods, and financing terms. As the time horizon considered becomes shorter than the expected useful lifetime, it becomes more critical to include the proper assessment of salvage or resale value in the TLCC analysis, and, hence, greater attention to this value is recommended when time horizons are short.

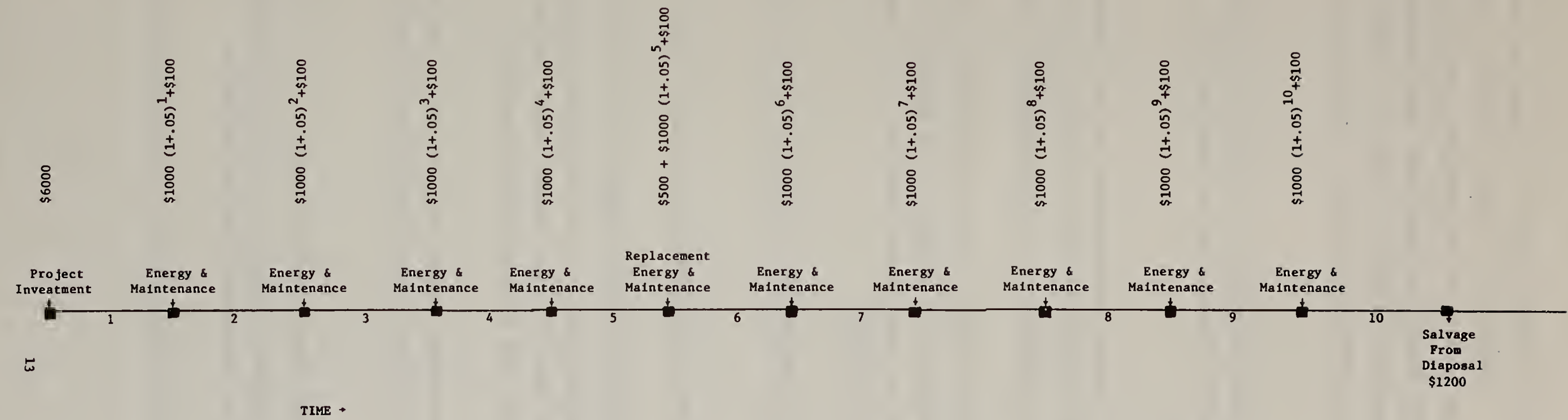
Costs and offsetting benefits which are not relevant to the decision can be omitted from the TLCC evaluation. For example, sunk costs, as well as those present and future costs which are not affected by the investment decision in question, need not be included in the TLCC evaluation.

4.2 CASH FLOWS

In addition to compiling the dollar amounts of the relevant costs and benefits, determine when each will occur. This information is essential for discounting dollars in past or future years to a common point in time.

A convenient and widely used diagrammatical aid for describing cash flows is a cash flow diagram such as the one illustrated in figure 1. Figure 1 shows the cash flows for a hypothetical project over 10 years. The initial investment is $6,000; the yearly non-fuel operating and maintenance cost is $100 in constant dollars; the yearly energy cost is $1,000 evaluated at present prices and is expected to increase each year at a compound rate 5 percent faster than general price inflation; the fifth year's replacement cost is $500 in constant dollars; the salvage value at the end of the 10 year time horizon is $1,200. The initial investment is assumed to occur at the beginning of the first year, i.e., the base period, and all other amounts are assumed to occur at the end of the year in which they accrue.

Figure 1. Illustration of a Cash Flow Diagram[a]



[a] Arrows above the acale indicate expenditurea (cash outflows). Arrows below the acale indicate receipta (cash inflows).

4.3 INFLATION

When all costs and benefits over the time horizon of an investment can be reasonably assumed to inflate at about the same rate as prices in general, and the income tax bracket of the investor is not expected to change significantly as inflation pushes prices (and nominal profits) higher, a "real" discount rate can be used to convert future constant dollar cash flows to present value.

When all costs over the time horizon cannot reasonably be expected to increase at the same rate, inflation should be included in a life-cycle cost analysis (1,6). Taking this approach, the following guidelines apply:

(1) Future costs that are fixed in amount and therefore are not responsive to inflation should not be adjusted to include inflation. Examples are loan payments and contracted future costs not subject to a price escalation clause.

(2) Future costs that are expected to change at rates significantly different from the general rate of price increase (e.g. energy costs) should be estimated on the basis of the specific rate of price change expected, be it faster or slower than the general rate of price increase.

(3) All other future costs should be estimated to reflect the rate of general price inflation.

(4) A "nominal" discount rate which includes inflation should be used.

As an alternative to including inflation in each cost category and in the discount rate, the general rate of inflation may be omitted from all cost escalation rates and from the discount rate, and only the differential rate of price change should then be included in each cost category. Taking this approach, the following guidelines apply:

(1) Those future costs expected to change faster than the rate of inflation should be increased only to reflect the rate of price escalation in excess of general inflation.

(2) Future costs expected to change slower than the general rate of inflation should be reduced to reflect the difference between the rate of price escalation for the particular cost category and the general rate of inflation.

(3) Those costs expected to increase approximately at the general rate of inflation should not be adjusted.

(4) Costs fixed in amount by contract should be reduced by exactly the rate of inflation in each year prior to discounting.

(5) A real discount rate should be used to convert future cash flows to present value.

5. DISCOUNT ALL CASH FLOWS TO A COMPARABLE TIME BASIS[1]

Fourth, discount all cash flows to a comparable time basis--either to present values or annual values. This step is necessary before the various costs can be summed to derive the TLCC measure.

Discounting is performed by applying discount formulas, or corresponding discount factors calculated from these formulas, to the estimated data associated with a given investment alternative. Table 1 depicts the most commonly used discounting formulas, indicates their use, and gives their algebraic form. Appendix A gives discounting factors based on the formulas in table 1 for selected discount rates and time periods.

Apply the appropriate formula or factor to a cash amount to convert it to its equivalent value at a selected time. Select a common time to adjust all cash amounts--either (1) the present, whereby all cash amounts are converted to an equivalent value occurring now, i.e., to a present value, or (2) annually, whereby all cash amounts are converted to a time equivalent value occurring in a uniform amount each year over the time horizon, i.e., to an annual value.

Table 2 illustrates the use of the discount formulas and factors to find present value and annual value equivalents for the same set of cost data given in figure 1.[2] Figure 2 illustrates graphically the relationship between these data and their equivalent present values. The sum of the present values shown at the top of the vertical axis is $15,048.

---

[1] The adjustment of all cash flows to a common-time equivalent value is necessary because a dollar received or expended in the base year does not have the same value as it would if it were received or expended in the future. One causal factor in the time dependency of value is the earning potential of money in hand (actually the resources money can buy). That is, a dollar received now can be put to use to generate additional income, whereas a dollar to be received in the future offers no earning potential in the interim. Similarly, an expense that must be paid now draws resources from the investor which cannot be used for other productive purposes. If the funds to meet the expense are borrowed, the investor must pay a borrowing charge to compensate the lender for the loss of income from failing to invest those funds in other endeavors. This earning potential of money is often called the opportunity cost of capital, and it occurs independently of inflation or deflation. The second causal factor in the time dependency of value is the change in the purchasing power of the dollar reflected in price inflation or price deflation.

[2] For any given set of cost data and assumptions, the present value of an investment and the annual value of the same investment are time equivalent values.

TABLE 1. DISCOUNT FORMULAS

Formula Name	Illustration	Use	Algebraic Form
Single Compound Amount Formula (SCA)	P → F?	To find F when P is known	$F = P \cdot (1 + i)^N$
Single Present Value Formula (SPW)	P? ← F	To find P when F is known	$P = F \cdot \frac{1}{(1 + i)^N}$
Uniform Sinking Fund Formula (USF)	A? + A? · · A? → F	To find A when F is known	$A = F \cdot \frac{1}{(1 + i)^N - 1}$
Uniform Capital Recovery Formula (UCR)	P → A? + A? · · · · A?	To find A when P is known	$A = P \cdot \frac{i(1 + i)^N}{(1 + i)^N - 1}$
Uniform Compound Amount Formula (UCA)	A + A · · A → F?	To find F when A is known	$F = A \cdot \frac{(1 + i)^N - 1}{i}$
Uniform Present Value Formula (UPW)	P? ← A + A · · · · A	To find P when A is known	$P = A \frac{(1 + i)^N - 1}{i(1 + i)^N}$
Uniform Present Value Formula Modified (UPW*)	P? ← A + A · · · A	To find P when A is escalating at rate e[§]	$P = A \left(\frac{1 + e}{i - e}\right)\left(1 - \left(\frac{1 + e}{1 + i}\right)^N\right)$

Where:

P = a present sum of money.

F = a future sum of money.

i = an interest or discount rate for the period being considered.

N = number of interest or discounting periods.

A = an end-of-period payment (or receipt) in a uniform series of payments (or receipts) over N periods at i interest or discount rate.

e = rate of escalation of A in each of N periods.

F? = indicates a future value to be found; P?, a present value to be found; and A?, an annual value to be found.

[§] To find P when A is escalating at a different rate over each of k escalation periods,

$$P = A \sum_{j=1}^{n_1} \left(\frac{1 + e_1}{1 + i}\right)^j + \left(\frac{1 + e_1}{1 + i}\right)^{n_1} \sum_{j=1}^{n_2} \left(\frac{1 + e_2}{1 + i}\right)^j + \ldots .$$

$$+ \left(\frac{1 + e_1}{1 + i}\right)^{n_1} \left(\frac{1 + e_2}{1 + i}\right)^{n_2} \cdots \left(\frac{1 + e_{k-1}}{1 + i}\right)^{n_{k-1}} \sum_{j=1}^{n_k} \left(\frac{1 + e_k}{1 + i}\right)^k$$

where n_h = the length of the period for a given escalation rate in a given period, and the subscript h indicates the escalation period; and

$$\sum_{j=1}^{n_h} \left(\frac{1 + e_h}{1 + i}\right)^j = \left(\frac{1 + e_h}{i - e_h}\right)\left(1 - \left(\frac{1 + e_h}{1 + i}\right)^{n_h}\right)$$

TABLE 2. ILLUSTRATION OF DISCOUNTING CASH FLOWS
(Based on a Time Horizon of 10 Years, a Real Discount Rate of 8%, and End-of-Year Payments)

Description of Cash Flow	Discounting to Present Value Equivalents			Discounting to Annual Value Equivalents		
	Discount Formula[a]	Corresponding Discount Factor[b]	Present Value, Dollars[c]	Discount Formula	Corresponding Discount Factor	Annual Value, Dollars[d]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Initial Investment cost of $6,000	n.a.[e]	1	6,000	UCR	0.903	894
Replacement Cost in 5th year of $500, constant $	SPW	0.6806	340	UCR	0.14903	51
Yearly (non-energy) O&M Cost over 10 years of $100, Constant $	UPW	6.710	671	UCR	0.14903	100
Yearly Energy Cost over 10 years, beginning at $1,000, in base period dollars, and escalating at a rate of 5% per year	UPW*	8.5923	8,593	UCR	0.14903	1,281
Salvage value of $1,200 at end of 10th year, constant $	SPW	0.4632	556	UCR	0.14903	83

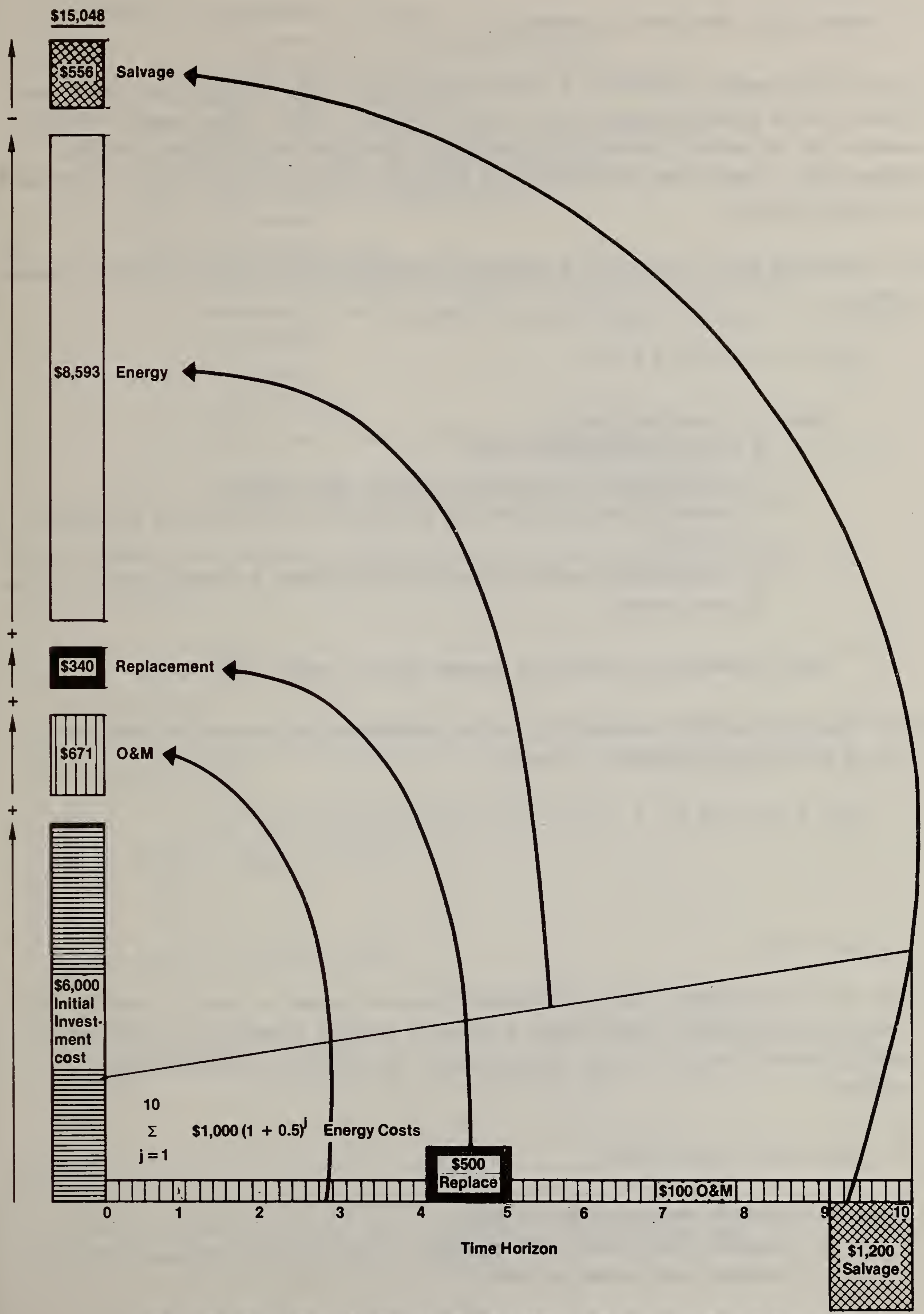
[a] From table 1.

[b] From appendix A.

[c] Col. 4 = amount in col. 1 x discount factor in col. 3.

[d] Col. 7 = amount in col. 4 x discount factor in col. 6.

[e] No discounting necessary.



Note: Corresponds to Cash Flows Given in Figure 1, and Present Value Discounting Operations Shown in Table 2.

Figure 2. Illustration of Discounting Cash Flows to Present Value

6. COMPUTE TLCC's AND COMPARE ALTERNATIVES

After all cash amounts relevant to a given investment have been discounted to present value or annual value dollars, combine them to obtain a measure of TLCC. Then compare the TLCC measures for the various investment alternatives to determine the alternative with the minimum TLCC. Other things being equal, the alternative with the lowest TLCC is preferred on economic grounds.

On a before-tax basis, the TLCC of a building or building system can be formulated in simple terms as

$$TLCC = C + R - S + A + N + E, \qquad (1)$$

where C = investment costs,
R = capital replacement costs,
S = resale value of investment at end of study period,
A = annually recurring operating maintenance and repair costs (except fuel costs),
N = non-annually operating recurring maintenance, and repair costs,
E = fuel costs,

and all costs are in life-cycle present value or annual value dollars.

A more comprehensive TLCC analysis will include adjustments for financing of investment costs as well as tax adjustments.[1] That is,

$$TLCC = D + F + P + R - S - T_d - T_i - T_c + T_g + A + N + E + T_p - T_o \qquad (2)$$

---

[1] Note that all tax credits and tax deductible items are assumed to result in end-of-year cash flows. In computing income taxes, a composite marginal income tax rate (Tl) comprising Federal, State, and local taxes is used. This rate may be calculated as follows:

$$Tl = T_F (1 - T_S - T_L) + T_S + T_L,$$

where T_F = marginal Federal income tax rate,
T_S = marginal State income tax rate, and
T_L = marginal local income tax rate.

where D = down payment on project,

F = all finance costs and principal payments,

P = any principal remaining at end of study period,

R = capital replacement costs,

S = resale value of investment at end of study period,

T_d = tax savings from depreciation allowance,

T_i = tax savings from interest payments,

T_c = tax credits,

T_g = capital gains taxes,

A = annually recurring operating, maintenance and repair costs,

N = non-annually recurring operating, maintenance and repair costs (except fuel costs),

E = fuel costs,

T_p = property taxes,

T_o = tax savings for all operating-related costs (i.e., for A, N, E, T_p),

and all costs are in life-cycle present value or annual value dollars.

The cost components of this more comprehensive TLCC can be calculated in present value dollars as follows*:

$$D = C_1 - F_1 (1 - F_5) \tag{3}$$

$$F = (F_1)(F_7)(F_9) \tag{4}$$

$$P = X_{1,N1}/(1 + I1)^{N1} \tag{5}$$

$$R = \sum_{k=1}^{C_{12}} (R_k) ((1 + C_7)/(1 + I1))^{Y_k} \tag{6}$$

$$S = (C_1) (C_{11})((1 + C_7)/(1 + I1))^{C_{13}} \tag{7}$$

$$T_d = \sum_{j=1}^{N1} (Z_{\alpha,j}) (T1)/(1 + I1)^j \tag{8}$$

---

* All notation to right of "equals" sign is consistent with variables used in the TLCC computer program given in appendix B.

$$T_i = \sum_{j=1}^{N1} (X_{2,j}) (T1)/(1 + I1)^j \qquad (9)$$

$$T_c = (C_9) (C_1)/(1+I1) \qquad (10)$$

$$T_g = [(D7 - (C_1 - D_1)) (T3) + (D_2 - D_1) (T1)]/(1 + I1)^{C_{13}} \text{ if } D7 \geq (C_1 - D_1), \qquad (11)$$

or

$$T_g = [(D7 - (C_1 - D_2)) (T1)]/(1 + I1)^{C_{13}} \text{ if } (C_1 - D_1) > D7 \geq (C_1 - D_2) \qquad (12)$$

$$A = (M1) (M3) \qquad (13)$$

$$N = \sum_{j=1}^{M4} (M_{2,j}) ((1 + M5)/(1 + I1))^{M_{1,j}} \qquad (14)$$

$$E = (E_1) (E_3) \qquad (15)$$

$$T_p = \sum_{j=1}^{C_{13}} (C_1 - D8) (C_8) (T2) ((1 + C_7)/(1 + I1))^{j-1} \qquad (16)$$

(Property tax in the first year is calculated as a percentage of the assessed value of the asset, which in turn is a percentage of the first cost. In order to determine the base value for estimating assessed value in future years, the asset is "depreciated" over its actual expected useful life on a straight-line basis. The resulting depreciated value is then adjusted upwards each year by the rate of cost inflation for that asset category.)

$$T_o = (A + N + E + T_p) (T1) \qquad (17)$$

where:

C_1 = total purchase cost,
C_7 = cost inflation rate,
C_8 = first year assessed value for property tax basis (% of C_1),
C_9 = investment tax credit (% of C_1),
C_{10} = actual expected useful life,
C_{11} = estimated resale value at end of useful life or end of study period, whichever comes first (% of C_1 in base-year dollars),
C_{12} = number of replacements during study period,
C_{13} = actual expected life of capital investment or study period, whichever is shorter,

D_1 = accumulated depreciation using straight-line method,

D_2 = accumulated depreciation using alternative method,

D7 = actual selling price = $(C_1)(C_{11})(1 + C_7)^{C_{13}}$,

E_1 = annual fuel costs in base-year prices,

E_3 = UPW* factor based on cost inflation rates for the fuel type used, study period, and discount rate,

F_1 = amount borrowed,

F_2 = life of loan,

F_3 = loan interest rate,

F_4 = number of payments per year,

F_5 = "points" paid (% of F_1),

F_7 = uniform capital recovery (UCR) factor for given interest rate (F_3) and loan life (F_2),

F_8 = loan life (F_2) or study period length (N1), whichever is shorter,

F_9 = uniform present value factor for given discount rate (I1) and time period (F_8),

I1 = discount rate,

M1 = annually recurring operation, maintenance and repair costs (except fuel costs), in base-year dollars,

M2 = cost inflation rate for operation, maintenance and repair cost (except fuel costs),

M3 = UPW* factor based on study period (N1), cost inflation rate (M2), and discount rate (I1),

M4 = number of non-annually recurring operation, maintenance and repair costs (except fuel costs),

M5 = cost inflation rate for non-annually recurring operation, maintenance and repair costs,

N1 = study period length,

R_k = kth capital replacement cost, in base-year dollars,

T1 = marginal income tax rate (composite Federal, State and local),

T2 = property tax rate,

T3 = capital gains tax rate,

$X_{2,j}$ = interest paid in year j*,

Y_k = year of kth capital replacement, and

$Z_{2,j}$ = amount of depreciation taken in year j.

---

* Assuming equal loan payments in each time period,

$$X_{2,j} = \sum_{j=1}^{F_4} (X_{3,k-1}) (F_2/F_4)$$

where $X_{3,k}$ = remaining principal after each loan payment, k = 1, 2...,
F_4; $X_{3,0}$ = remaining principal at end of previous year.

7. RECOMMENDED APPLICATIONS

The TLCC measure can be used to determine whether or not to make an investment. For example, if the addition of insulation to a building reduces the TLCC (i.e., the reduction in energy costs outweighs the increase in the investment costs), then it is economical to make that investment.

The TLCC technique can also be used to determine the efficient level of investment (i.e., scale or size of investment). For example, as long as the TLCC falls with added insulation, it is profitable to increase the insulation level. If the TLCC increases with added insulation, it is not profitable to increase the insulation level. The economically efficient (or optimal) level of insulation is the level for which TLCC is minimized.

Substitutable investment projects for a given purpose can be compared by examining their TLCC's, provided they are evaluated over the same time horizon. For example, if a building owner has a choice between a conventional heating/cooling system and a solar energy system with a conventional system backup, both of which meet thermal performance requirements, the system with the lower TLCC would be the more cost effective as long as other things were equal (11-13).

A limitation on the application of the TLCC technique is for allocating a limited budget among investment projects. Because it does not provide a measure of the return per investment dollar, choosing investment projects on the basis of their TLCC measures alone will not necessarily result in the largest possible cost reductions for a given budget. The benefit/cost or savings-to-investment ratio technique or the internal-rate-of-return technique are preferred to the TLCC technique for allocating limited budgets among multiple investment opportunities for maximum economic efficiency.

8. ELEMENTS OF A TLCC REPORT

A report of a TLCC analysis should state the objective, the constraints, the alternatives considered, and the key assumptions and data. Items whose values should be made explicit include the discount rate, the time horizon, and the main categories of cost data, including initial costs, recurring and non-recurring costs, resale values, and grants, tax deductibles, credits, and expenses, as well as financing terms if applicable. The tax status of the investor should be given, together with the method of treating inflation, and the level of comprehensiveness of the analysis. Any significant effects that remain unquantified should also be described in the TLCC report.

Two examples of applying the TLCC technique to building investment problems are given in appendices to this report. Appendix B, which contains a computer program for calculating TLCC, gives an illustrative case example solved by the computer program. The computer printout includes a display of the key elements that are necessary for an understanding of the problem and its solution. Appendix C presents an additional problem example--this one solved manually step by step in tabular form. Again, the objective, the alternatives, and the key data and assumptions are set forth, as well as the conclusions.

APPENDIX A

Discount Factors

Table A-1 6% Discount Factors

n	Single Compound amount factor SCA	Single Present value factor SPW	Sinking fund factor USF	Uniform Capital recovery factor UCR	Uniform Compound amount factor UCA	Uniform Present value factor UPW	n
1	2	3	4	5	6	7	n
1	1.0600	0.9434	1.00000	1.06000	1.000	0.943	1
2	1.1236	0.8900	0.48544	0.54544	2.060	1.833	2
3	1.1910	0.8396	0.31411	0.37411	3.184	2.673	3
4	1.2625	0.7921	0.22859	0.22859	4.375	3.465	4
5	1.3382	0.7473	0.17740	0.27340	5.637	4.212	5
6	1.4185	0.7050	0.14336	0.20336	6.975	4.917	6
7	1.5036	0.6641	0.11914	0.17914	8.394	5.582	7
8	1.5938	0.6274	0.10104	0.16104	9.897	6.210	8
9	1.6895	0.5919	0.08702	0.14702	11.491	6.802	9
10	1.7908	0.5584	0.70587	0.13587	13.181	7.360	10
11	1.8983	0.5268	0.06679	0.12679	14.972	7.887	11
12	2.0122	0.4970	0.05928	0.11928	16.870	8.384	12
13	2.1329	0.4688	0.05296	0.11296	18.882	8.853	13
14	2.2609	0.4423	0.04758	0.10758	21.015	9.295	14
15	2.3966	0.4173	0.04296	0.10296	23.276	9.712	15
16	2.5404	0.3936	0.03895	0.09895	25.673	10.106	16
17	2.6928	0.3714	0.03544	0.09544	28.213	10.477	17
18	2.8543	0.3503	0.03236	0.09236	30.906	10.828	18
19	3.0256	0.3305	0.02962	0.08962	33.760	11.158	19
20	3.2071	0.3118	0.02718	0.08718	36.786	11.470	20
21	3.3996	0.2942	0.02500	0.08500	39.993	11.764	21
22	3.6035	0.2775	0.02305	0.08305	43.392	12.042	22
23	3.8197	0.2618	0.02128	0.08128	46.996	12.303	23
24	4.0489	0.2470	0.01968	0.07968	50.816	12.550	24
25	4.2919	0.2330	0.01823	0.07823	54.865	12.783	25
26	4.5494	0.2198	0.01690	0.07690	59.156	13.003	26
27	4.8223	0.2074	0.01570	0.07570	63.706	13.211	27
28	5.1117	0.1956	0.01459	0.07459	68.528	13.406	28
29	5.4184	0.1846	0.01358	0.07358	73.640	13.591	29
30	5.7435	0.1741	0.01265	0.07265	79.058	13.765	30
31	6.0881	0.1643	0.01179	0.07179	84.802	13.929	31
32	6.4534	0.1550	0.01100	0.07100	90.890	14.084	32
33	6.8406	0.1462	0.01027	0.07027	97.343	14.230	33
34	7.2510	0.1379	0.00960	0.06960	104.184	14.368	34
35	7.6861	0.1301	0.00897	0.06897	111.435	14.498	35
40	10.2857	0.0972	0.00646	0.06646	154.762	15.046	40
45	13.7646	0.0727	0.00470	0.06470	212.744	15.456	45
50	18.4202	0.0543	0.00344	0.06344	290.336	15.762	50
55	24.6503	0.0406	0.00254	0.06254	394.172	15.991	55
60	32.9877	0.0303	0.00188	0.06188	533.128	16.161	60
65	44.1450	0.0227	0.00139	0.06139	719.083	16.289	65
70	59.0759	0.0169	0.00103	0.06103	967.932	16.385	70
75	79.0569	0.0126	0.00077	0.06077	1300.949	16.456	75
80	105.7960	0.0095	0.00057	0.06057	1746.600	16.509	80
85	141.5789	0.0071	0.00043	0.06043	2342.982	16.549	85
90	189.4645	0.0053	0.00032	0.06032	3141.075	16.579	90
95	253.5463	0.0039	0.00024	0.06024	4209.104	16.601	95
100	339.3021	0.0029	0.00018	0.06018	5638.368	16.618	100

Table A-2 8% Discount Factors

n	Single Compound amount factor SCA	Single Present value factor SPW	Sinking fund factor USF	Uniform Capital recovery factor UCR	Uniform Compound amount factor UCA	Uniform Present value factor UPW	
1	2	3	4	5	6	7	
1	1.0800	0.9259	1.00000	1.08000	1.000	0.926	1
2	1.664	.8573	0.48077	0.56077	2.080	1.783	2
3	1.2597	.7938	.30803	.38803	3.246	2.577	3
4	1.3605	.7350	.22192	.30192	4.506	3.312	4
5	1.4693	.6806	.17046	.25046	5.867	3.993	5
6	1.5869	.6302	.13632	.21632	7.336	4.623	6
7	1.7138	.5835	.11207	.19207	8.923	5.206	7
8	1.8509	.5403	.09401	.17401	10.637	5.747	8
9	1.9990	.5002	.08008	.16008	12.488	6.247	9
10	2.1589	.4632	.06903	.14903	14.487	6.710	10
11	2.3316	.4289	.06008	.14008	16.645	7.139	11
12	2.5182	.3971	.05270	.13270	18.977	7.536	12
13	2.7196	.3677	.04652	.12652	21.495	7.904	13
14	2.9372	.3405	.04130	.12130	24.215	8.244	14
15	3.1722	.3152	.03683	.11683	27.152	8.559	15
16	3.4259	.2919	.03298	.11298	30.324	8.851	16
17	3.7000	.2703	.02963	.10963	33.750	9.122	17
18	3.9960	.2502	.02670	.10670	37.450	9.372	18
19	4.3157	.2317	.02413	.10413	41.446	9.604	19
20	4.6610	.2145	.02185	.10185	45.762	9.818	20
21	5.0338	.1987	.01983	.09983	50.423	10.017	21
22	5.4365	.1839	.01803	.09803	55.457	10.201	22
23	5.8715	.1703	.01642	.09642	60.893	10.371	23
24	6.3412	.1577	.01498	.09498	66.765	10.529	24
25	6.8485	.1460	.01368	.09368	73.106	10.675	25
26	7.3964	.1352	.01251	.09251	79.954	10.810	26
27	7.9881	.1252	.01145	.09145	87.351	10.935	27
28	8.6271	.1159	.01049	.09049	95.339	11.051	28
29	9.3173	.1073	.00962	.08962	103.966	11.158	29
30	10.0627	.0994	.00883	.08883	113.283	11.258	30
31	10.8677	.0920	.00811	.08811	123.346	11.350	31
32	11.7371	.0852	.00745	.08745	134.214	11.435	32
33	12.6760	.0789	.00685	.08685	145.951	11.514	33
34	13.6901	.0730	.00630	.08630	158.627	11.587	34
35	14.7853	.0676	.00580	.08580	172.317	11.655	35
40	21.7245	.0460	.00386	.08386	259.057	11.925	40
45	31.9204	.0313	.00259	.08259	386.506	12.108	45
50	46.9016	.0213	.00174	.08174	573.770	12.233	50
55	68.9139	.0145	.00118	.03118	848.923	12.319	55
60	101.2571	.0099	.00080	.08080	1253.213	12.377	60
65	148.7798	.0067	.00054	.08054	1847.248	12.416	65
70	218.6064	.0046	.00037	.08037	2720.080	12.443	70
75	321.2045	.0031	.00025	.08025	4002.557	12.461	75
80	471.9548	.0021	.00017	.08017	5886.935	12.474	80
85	693.4565	.0014	.00012	.08012	8655.706	12.482	85
90	1018.9151	.0010	.00008	.08008	12723.939	12.488	90
95	1497.1205	.0007	.00005	.08005	18701.507	12.492	95
100	2199.7613	.0005	.00004	.08004	27484.516	12.494	100

Table A-3 10% Discount Factors

n	Single Compound amount factor SCA	Single Present value factor SPW	Sinking fund factor USF	Uniform Capital recovery factor UCR	Uniform Compound amount factor UCA	Uniform Present value factor UPW	
1	2	3	4	5	6	7	n
1	1.1000	0.9091	1.00000	1.10000	1.000	0.909	1
2	1.2100	0.8264	0.47619	0.57619	2.100	1.736	2
3	1.3310	0.7513	0.30211	0.40211	3.310	2.487	3
4	1.4641	0.6830	0.21547	0.31547	4.641	3.170	4
5	1.6105	0.6209	0.16380	0.26380	6.105	3.791	5
6	1.7716	0.5645	0.12961	0.22961	7.716	4.355	6
7	1.9487	0.5132	0.10541	0.20541	9.487	4.868	7
8	2.1436	0.4665	0.08744	0.18744	11.436	5.335	8
9	2.3579	0.4241	0.07364	0.17364	13.579	5.759	9
10	2.5937	0.3855	0.06275	0.16275	15.937	6.144	10
11	2.8531	0.3505	0.05396	0.15396	18.531	6.495	11
12	3.1384	0.3186	0.04676	0.14676	21.384	6.814	12
13	3.4523	0.2897	0.04078	0.14078	24.523	7.103	13
14	3.7975	0.2633	0.03575	0.13575	27.975	7.367	14
15	4.1772	0.2394	0.03147	0.13147	31.772	7.606	15
16	4.5950	0.2176	0.02782	0.12782	35.950	7.824	16
17	5.0545	0.1978	0.02466	0.12466	40.545	8.022	17
18	5.5599	0.1799	0.02193	0.12193	45.599	8.201	18
19	6.1159	0.1635	0.01955	0.11955	51.159	8.365	19
20	6.7275	0.1486	0.01746	0.11746	57.275	8.514	20
21	7.4002	0.1351	0.01562	0.11562	64.002	8.649	21
22	8.1403	0.1228	0.01401	0.11401	71.403	8.772	22
23	8.9543	0.1117	0.01257	0.11257	79.543	8.883	23
24	9.8497	0.1015	0.01130	0.11130	88.497	8.985	24
25	10.8347	0.0923	0.1017	0.11017	98.347	9.077	25
26	11.9182	0.0839	0.00916	0.10916	109.182	9.161	26
27	13.1100	0.0763	0.00826	0.10826	121.100	9.237	27
28	14.4210	0.0693	0.00745	0.10745	134.210	9.307	28
29	15.8631	0.0630	0.00673	0.10673	148.631	9.370	29
30	17.4494	0.0573	0.00609	0.10608	164.494	9.427	30
31	19.1943	0.0521	0.00550	0.10550	181.943	9.479	31
32	21.1138	0.0474	0.00497	0.10497	201.138	9.526	32
33	23.2252	0.0431	0.00450	0.10450	222.252	9.569	33
34	25.5477	0.0391	0.00407	0.10407	245.477	9.609	34
35	28.1024	0.0356	0.03369	0.10369	271.024	9.644	35
40	45.2593	0.0221	0.00226	0.10226	442.593	9.779	40
45	72.8905	0.0137	0.00139	0.10139	718.905	9.863	45
50	117.3909	0.0085	0.00086	0.10086	1163.909	9.915	50
55	189.0591	0.0053	0.00053	0.10053	1880.591	9.947	55
60	304.4816	0.0033	0.00033	0.10033	3034.816	9.967	60
65	490.3707	0.0020	0.00020	0.10020	4893.707	9.980	65
70	789.7470	0.0013	0.00013	0.10013	7887.470	9.987	70
75	1271.8952	0.0008	0.00008	0.10008	12708.954	9.992	75
80	2048.4002	0.0005	0.00005	0.10005	20474.002	9.995	80
85	3298.9690	0.0003	0.00003	0.10003	32979.690	9.997	85
90	5313.0226	0.0002	0.00002	0.10002	53120.226	9.998	90
95	8556.6760	0.0001	0.00001	0.10001	85556.760	9.999	95
100	13780.6123	0.0001	0.00001	0.10001	137796.123	9.999	100

Table A-4 12% Discount Factors

n 1	Single Compound amount factor SCA 2	Single Present value factor SPW 3	Sinking fund factor USF 4	Uniform Capital recovery factor UCR 5	Uniform Compound amount factor UCA 6	Uniform Present value factor UPW 7	n
1	1.1200	0.8929	1.00000	1.12000	1.000	0.893	1
2	1.2544	0.7972	0.47170	0.59170	2.120	1.690	2
3	1.4049	0.7118	0.29635	0.41635	3.374	2.402	3
4	1.5735	0.6355	0.20923	0.32923	4.779	3.037	4
5	1.7623	0.5674	0.15741	0.27741	6.353	3.605	5
6	1.9738	0.5066	0.12323	0.24323	8.115	4.111	6
7	2.2107	0.4523	0.09912	0.21912	10.089	4.564	7
8	2.4760	0.4039	0.08130	0.20130	12.300	4.968	8
9	2.7731	0.3606	0.06768	0.18768	14.776	5.328	9
10	3.1058	0.3220	0.05698	0.17698	17.549	5.650	10
11	3.4785	0.2875	0.04842	0.16842	20.655	5.938	11
12	3.8960	0.2567	0.04144	0.16144	24.133	6.194	12
13	4.3635	0.2292	0.03568	0.15568	23.029	6.424	13
14	4.8871	0.2046	0.03087	0.15087	32.393	6.628	14
15	5.4736	0.1827	0.02682	0.14682	37.280	6.811	15
16	6.1304	0.1631	0.02339	0.14339	42.753	6.974	16
17	6.8660	0.1456	0.02046	0.14046	48.884	7.120	17
18	7.6900	0.1300	0.01794	0.13794	55.750	7.250	18
19	8.6463	0.1161	0.01576	0.13576	63.440	7.366	19
20	9.6463	0.1037	0.01388	0.13388	72.052	7.469	20
21	10.8038	0.0926	0.01224	0.13224	81.699	7.562	21
22	12.1003	0.0826	0.01081	0.13081	92.503	7.645	22
23	13.5523	0.0738	0.00956	0.12956	104.603	7.718	23
24	15.1786	0.0659	0.00846	0.12846	118.155	7.784	24
25	17.0001	0.0588	0.00750	0.12750	133.334	7.843	25
26	19.0401	0.0525	0.00665	0.12665	150.334	7.896	26
27	21.3249	0.0469	0.00590	0.12590	169.374	7.943	27
28	23.8839	0.0419	0.00524	0.12524	190.699	7.984	28
29	26.7499	0.0374	0.00466	0.12466	214.583	8.022	29
30	29.9599	0.0334	0.00414	0.12414	241.333	8.055	30
31	33.5551	0.0298	0.00369	0.12369	271.292	8.085	31
32	37.5817	0.0266	0.00328	0.12328	304.847	8.112	32
33	42.0915	0.0238	0.00292	0.12292	342.429	8.135	33
34	47.1425	0.0212	0.00260	0.12260	384.520	8.157	34
35	52.7996	0.0189	0.00232	0.12232	431.663	8.176	35
40	93.0510	0.0107	0.00130	0.12130	767.091	8.244	40
45	163.9876	0.0061	0.00074	0.12074	1358.230	8.283	45
50	289.0022	0.0035	0.00042	0.12042	2400.018	8.305	50
∞	--	--	--	0.12000	--	8.333	∞

Table A-5   15% Discount Factors

n 1	Single Compound amount factor SCA 2	Single Present value factor SPW 3	Sinking fund factor USF 4	Uniform Capital recovery factor UCR 5	Uniform Compound amount factor UCA 6	Uniform Present value factor UPW 7	n
1	1.1500	0.8696	1.00000	1.15000	1.000	0.870	1
2	1.3225	0.7561	0.46512	0.61512	2.150	1.626	2
3	1.5209	0.6575	0.28798	0.43798	3.472	2.283	3
4	1.7490	0.5718	0.20026	0.35027	4.993	2.855	4
5	2.0114	0.4972	0.14832	0.29832	6.742	3.352	5
6	2.3131	0.4323	0.11424	0.26424	8.754	3.784	6
7	2.6600	0.3759	0.09036	0.24036	11.067	4.160	7
8	3.0590	0.3269	0.07285	0.22285	13.727	4.487	8
9	3.5179	0.2843	0.05957	0.29057	16.786	4.772	9
10	4.0456	0.2472	0.04925	0.19925	20.304	5.019	10
11	4.6524	0.2149	0.04107	0.19107	24.349	5.234	11
12	5.3503	0.1869	0.03448	0.18448	29.002	5.421	12
13	6.1528	0.1625	0.02911	0.17911	34.352	5.583	13
14	7.0757	0.1413	0.02469	0.17569	40.505	5.724	14
15	8.1371	0.1229	0.02102	0.17102	47.580	5.847	15
16	9.3576	0.1069	0.01795	0.16795	55.717	5.954	16
17	10.7613	0.0929	0.01537	0.16537	65.075	6.047	17
18	12.3755	0.0808	0.01319	0.16319	75.836	6.128	18
19	14.2318	0.0703	0.01134	0.16134	88.212	6.198	19
20	16.3665	0.0611	0.00976	0.15976	102.444	6.259	20
21	18.8215	0.0531	0.00842	0.15842	118.810	6.312	21
22	21.6447	0.0462	0.00727	0.15727	137.632	6.359	22
23	24.8915	0.0402	0.00628	0.15628	159.276	6.399	23
24	28.6252	0.0349	0.00543	0.15543	184.168	6.434	24
25	32.9190	0.0304	0.00470	0.15470	212.793	6.464	25
26	37.8568	0.0264	0.00407	0.15407	245.712	6.491	26
27	45.5353	0.0230	0.00353	0.15353	283.569	6.514	27
28	50.0656	0.0200	0.00306	0.15306	327.104	6.534	28
29	57.5755	0.0174	0.00265	0.15265	377.170	6.551	29
30	66.2118	0.0151	0.00230	0.15230	434.745	6.566	30
31	76.1435	0.0131	0.00200	0.15200	500.957	6.579	31
32	87.5651	0.0114	0.00173	0.15173	577.100	6.591	32
33	100.6998	0.0099	0.00150	0.15150	664.666	6.600	33
34	115.8048	0.0086	0.00131	0.15131	765.365	6.609	34
35	133.1755	0.0075	0.00113	0.15113	881.170	6.617	35
40	267.8635	0.0037	0.00056	0.15056	1779.090	6.642	40
45	538.7693	0.0019	0.00028	0.15028	3585.128	6.654	45
50	1083.6574	0.0009	0.00014	0.15014	7217.716	6.661	50
∞	--	--	--	0.15000	--	6.667	∞

Table A-6 20% Discount Factors

n 1	Single Compound amount factor SCA 2	Single Present value factor SPW 3	Sinking fund factor USF 4	Uniform Capital recovery factor UCR 5	Uniform Compound amount factor UCA 6	Uniform Present value factor UPW 7	n
1	1.2000	0.8333	1.00000	1.20000	1.000	0.833	1
2	1.4400	0.6944	0.45455	0.65455	2.200	1.528	2
3	1.7280	0.5787	0.27473	0.47473	3.640	2.106	3
4	2.0736	0.4823	0.18629	0.38629	5.368	2.589	4
5	2.4883	0.4019	0.13438	0.33438	7.442	2.991	5
6	2.9860	0.3349	0.10071	0.30071	9.930	3.326	6
7	3.5832	0.2791	0.07742	0.27742	12.916	3.605	7
8	4.2998	0.2326	0.06061	0.26061	16.499	3.837	8
9	5.1598	0.1938	0.04808	0.24808	20.799	4.031	9
10	6.1917	0.1615	0.03852	0.23852	25.959	4.192	10
11	7.4301	0.1346	0.03110	0.23110	32.150	4.327	11
12	8.9161	0.1122	0.02526	0.22526	39.581	4.439	12
13	10.6993	0.0935	0.02062	0.22062	48.497	4.533	13
14	12.8392	0.0779	0.01689	0.21689	59.196	4.611	14
15	15.4070	0.0649	0.01388	0.21388	72.035	4.675	15
16	18.4884	0.0541	0.01144	0.21144	87.442	4.730	16
17	22.1861	0.0451	0.00944	0.20944	105.931	4.775	17
18	26.6233	0.0376	0.00781	0.20781	128.117	4.812	18
19	31.9480	0.0313	0.00646	0.20646	154.740	4.844	19
20	38.3376	0.0261	0.00536	0.20536	186.688	4.870	20
21	46.0051	0.0217	0.00444	0.20444	225.026	4.891	21
22	55.2061	0.0181	0.00369	0.20369	271.031	4.909	22
23	66.2474	0.0151	0.00307	0.20307	326.237	4.925	23
24	79.4968	0.0126	0.00255	0.20255	392.484	4.937	24
25	95.3962	0.0105	0.00212	0.20212	471.981	4.949	25
26	114.4755	0.0087	0.00176	0.20176	567.377	4.956	26
27	137.3706	0.0073	0.00147	0.20147	681.853	4.964	27
28	164.8447	0.0061	0.00122	0.20122	819.223	4.970	28
29	197.8136	0.0051	0.00102	0.20102	984.068	4.975	29
30	237.3763	0.0042	0.00085	0.20085	1181.882	4.979	30
31	284.8516	0.0035	0.00070	0.20070	1419.258	4.982	31
32	341.8219	0.0029	0.00059	0.20059	1704.109	4.985	32
33	410.1863	0.0024	0.00049	0.20049	2045.931	4.988	33
34	492.2235	0.0020	0.00041	0.20041	2456.118	4.990	34
35	590.6682	0.0017	0.00034	0.20034	2948.341	4.992	35
40	1469.7716	0.0007	0.00014	0.20014	7343.858	4.997	40
45	3657.2620	0.0003	0.00005	0.20005	18281.310	4.999	45
50	9100.4382	0.0001	0.00002	0.20002	45497.191	4.999	50
∞	--	--	--	0.20002	--	5.000	∞

Table A-7 8% UPW* Factors Modified for Energy Price Escalation

	Rate of Energy Price Escalation									
Year	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1	.9352	.9444	.9537	.9630	.9722	.9815	.9907	1	1.0093	1.0185
2	1.8098	1.8364	1.8633	1.8903	1.9174	1.9448	1.9723	2	2.0279	2.0559
3	2.6276	2.6788	2.7307	2.7832	2.8364	2.8903	2.9448	3	3.0559	3.1125
4	3.3925	3.4745	3.5580	3.6431	3.7298	3.8182	3.9083	4	4.0935	4.1887
5	4.1078	4.2259	4.3470	4.4711	4.5985	4.7290	4.8628	5	5.1406	5.2847
6	4.7768	4.9356	5.0994	5.2685	5.4429	5.6229	5.8085	6	6.1975	6.4011
7	5.4023	5.6058	5.8170	6.0363	6.2640	6.5003	6.7455	7	7.2641	7.5382
8	5.9874	6.2388	6.5014	6.7757	7.0622	7.3614	7.6738	8	8.3406	8.6983
9	6.5345	6.8367	7.1541	7.4877	7.8382	8.2065	8.5935	9	9.4271	9.8759
10	7.0461	7.4013	7.7766	8.1734	8.5923	9.0360	9.5046	10	10.5237	11.0773
11	7.5246	7.9346	8.3703	8.8336	9.3263	9.8502	10.4074	11	11.6304	12.3009
12	7.9726	8.4382	8.9365	9.4694	10.0394	10.6492	11.3017	12	12.7473	13.5472
13	8.3906	8.9138	9.4765	10.0817	10.7328	11.4335	12.1878	13	13.8746	14.8166
14	8.7819	9.3631	9.9915	10.6712	11.4069	12.2033	13.0657	14	15.0123	16.1095
15	9.1479	9.7873	10.4826	11.2390	12.0622	12.9588	13.9355	15	16.1606	17.4264
16	9.4902	10.1880	10.9510	11.7857	12.6994	13.7003	14.7972	16	17.3195	18.7676
17	9.8103	10.5665	11.3977	12.3121	13.3189	14.4280	15.6509	17	18.4891	20.1337
18	10.1096	10.9239	11.8237	12.8191	13.9211	15.1423	16.4967	18	19.6696	21.5250
19	10.3895	11.2615	12.2300	13.3073	14.5066	15.8434	17.3347	19	20.8610	22.9421
20	10.6513	11.5803	12.6175	13.7774	15.0759	16.5315	18.1650	20	22.0634	24.3855
21	10.8961	11.8814	12.9871	14.2301	15.6293	17.2068	18.9875	21	23.2769	25.8556
22	11.1251	12.1657	13.3395	14.6660	16.1674	17.8695	19.8025	22	24.5017	27.3529
23	11.3992	12.4343	13.6757	15.0858	16.6905	18.5202	20.6098	23	25.7378	28.8780
24	11.5894	12.6880	13.9963	15.4900	17.1991	19.1587	21.4097	24	26.9854	30.4313
25	11.7287	12.9275	14.3020	15.8792	17.6936	19.7884	22.2022	25	28.2445	32.0134

Table A-8 10% UPW* Factors Modified for Energy Price Escalation

Rate of Energy Price Escalation

Year	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1	0.9182	0.9273	0.9364	0.9455	0.9546	0.9636	0.9727	0.9818	0.9909	1.0000
2	1.7612	1.7871	1.8131	1.8393	1.9657	1.8921	1.9188	1.9457	1.9727	2.0000
3	2.5353	2.5844	2.6340	2.6844	2.7354	2.7869	2.8391	2.8921	2.9456	3.0000
4	3.2460	3.4027	3.4027	3.4834	3.5656	3.6492	3.7344	3.8213	3.9097	4.0000
5	3.8986	4.0092	4.1225	4.2388	4.3581	4.4801	4.6053	4.7336	4.8650	5.0000
6	4.4978	4.6449	4.7966	4.9531	5.1146	5.2808	5.4524	5.6294	5.8117	6.0000
7	5.0480	5.2344	5.4278	5.6284	5.8367	6.0524	6.2765	6.5089	6.7498	7.0000
8	5.5521	5.7810	6.0188	6.2669	6.5260	6.7959	7.0780	7.3723	7.6793	8.0000
9	6.0159	6.2878	6.5722	6.8705	7.1839	7.5124	7.8577	8.2201	8.6004	9.0000
10	6.4417	6.7577	7.0903	7.4411	7.8118	8.2028	8.6161	9.0524	9.5130	10.0000
11	6.8328	7.1935	7.5755	7.9807	8.4113	8.8682	9.3539	9.8696	10.4174	11.0000
12	7.1919	7.5977	8.0299	8.4909	8.9837	9.5095	10.0717	10.6722	11.3138	12.0000
13	7.5216	7.9725	8.4553	8.9733	9.5300	10.1274	10.7698	11.4601	12.2020	13.0000
14	7.8243	8.3199	8.8536	9.4293	10.0513	10.7227	11.4487	12.2335	13.0819	14.0000
15	8.1022	8.6421	9.2266	9.8604	10.5490	11.2964	12.1092	12.9929	13.9539	15.0000
16	8.3574	8.9408	9.5758	10.2680	11.0240	11.8492	12.7516	13.7384	14.8178	16.0000
17	8.5918	9.2179	9.9029	10.6535	11.4776	12.3821	13.3767	14.4706	15.6742	17.0000
18	8.8069	9.4747	10.2090	11.0177	11.9103	12.8953	13.9844	15.1891	16.5223	18.0000
19	9.0044	9.7129	10.4957	11.3622	12.3235	13.3900	14.5757	15.8947	17.3630	19.0000
20	9.1857	9.9337	10.7641	11.6878	12.7178	13.8666	15.1507	16.5873	18.1958	20.0000
21	9.3512	10.1385	11.0154	11.9957	13.0942	14.3259	15.7101	17.2674	19.0211	21.0000
22	9.5042	10.3285	11.2509	12.2870	13.4537	14.7688	16.2546	17.9355	19.8394	22.0000
23	9.6446	10.5046	11.4714	12.5623	13.7968	15.1955	16.7841	18.5913	20.6501	23.0000
24	9.7735	10.6679	11.6777	12.8225	14.1241	15.6065	17.2989	19.2349	21.4531	24.0000
25	9.8919	10.8193	11.8710	13.0686	14.4367	16.0026	17.7998	19.8670	22.2490	25.0000

Table A-9 12% UPW* Factors Modified for Energy Price Escalation

	Rate of Energy Price Escalation									
Year	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1	.9018	.9107	.9196	.9286	.9375	.9464	.9554	.9643	.9732	.9822
2	1.7150	1.7401	1.7654	1.7908	1.8164	1.8422	1.8681	1.8941	1.9204	1.9468
3	2.4484	2.4955	2.5432	2.5915	2.6404	2.6899	2.7400	2.7908	2.8421	2.8941
4	3.1097	3.1834	3.2585	3.3349	3.4129	3.4922	3.5731	3.6554	3.7392	3.8246
5	3.7061	3.8099	3.9163	4.0253	4.1371	4.2516	4.3690	4.4891	4.6123	4.7384
6	4.2438	4.3804	4.5212	4.6664	4.8160	4.9702	5.1292	5.2931	5.4620	5.6360
7	4.7288	4.9000	5.0775	5.2616	5.4525	5.6504	5.8556	6.0683	6.2889	6.5175
8	5.1662	5.3732	5.8292	5.8144	6.0492	6.2941	6.5495	6.8159	7.0936	7.3832
9	5.5606	5.8042	6.0597	6.3276	6.6086	6.9034	7.2125	7.5368	7.8768	8.2335
10	5.9162	6.1967	6.4924	6.8042	7.1331	7.4800	7.8459	8.2319	8.6391	9.0686
11	6.2370	6.5541	6.8903	7.2468	7.6248	8.0257	8.4510	8.9022	9.3809	9.8888
12	6.5262	6.8796	7.2563	7.6577	8.0857	8.5422	9.0291	9.5485	10.1028	10.6944
13	6.7870	7.1761	7.5928	8.0393	8.5179	9.0310	9.5813	10.1718	10.8054	11.4856
14	7.0222	7.4461	7.9023	8.3936	8.9230	9.4936	10.1089	10.7728	11.4892	12.2626
15	7.2343	7.6920	8.1870	8.7227	9.3028	9.9315	10.6130	11.3523	12.1547	13.0258
16	7.4256	7.9159	8.4487	9.0282	9.6589	10.3458	11.0946	11.9112	12.8023	13.7753
17	7.5981	8.1198	8.6895	9.3119	9.9927	10.7380	11.5546	12.4501	13.4326	14.5115
18	7.7536	8.3056	8.9108	9.5753	10.3057	11.1092	11.9942	12.9697	14.0460	15.2345
19	7.8939	8.4747	9.1144	9.8200	10.5991	11.4605	12.4141	13.4708	14.6430	15.9446
20	8.0204	8.6288	9.3017	10.0471	10.8741	11.7939	12.8152	13.9540	15.2240	16.6420
21	8.1345	8.7691	9.4739	10.2580	11.1320	12.1076	13.1985	14.4199	15.7894	17.3270
22	8.2373	8.8968	9.6322	10.4539	11.3737	12.4054	13.5646	14.8692	16.3397	17.9997
23	8.3301	9.0132	9.7778	10.6357	11.6004	12.6873	13.9144	15.3024	16.8752	18.6604
24	8.4137	9.1191	9.9118	10.8046	11.8129	12.9540	14.2486	15.7202	17.3964	19.3093
25	8.4892	9.2156	10.0349	10.9614	12.0121	13.2065	14.5678	16.1231	17.9037	19.9467

APPENDIX B

COMPUTER PROGRAM TO CALCULATE TOTAL LIFE-CYCLE COSTS

This section provides a comprehensive computer program, called TLCC, written in BASIC, which can calculate total life-cycle costs, in present-value and in annual-value form, associated with a building-related project. TLCC uses the algorithms described in section 6 of this report. The building-related project can be divided into a number of capital investment categories (e.g., land, building, equipment), in order to reflect differences in cost inflation rates, depreciation schedules, and/or tax treatments. Up to 10 capital investment categories can be defined and analyzed if such differentiation is warranted. An example of the output generated by TLCC is shown in table B-1, corresponding to the input data file shown in table B-2.

While the TLCC program is quite flexible in its ability to treat inflation and tax adjustments, it can also be used to solve simple problems where taxes and inflation are not considered. One of three tax status alternatives can be specified for the analysis: profit-making enterprise, tax-exempt status, and private residential (homeowner). Tax savings due to depreciation; operating, maintenance and repair (OM&R) costs; and fuel costs are not considered for the latter two categories. In addition, investment tax credits, property taxes, tax savings from interest, and capital gains taxes are not considered for the tax-exempt category, but they are included in the evaluation of homeowner investments.

Up to three separate financing arrangements can be analyzed, each with separate loan amounts, lengths, and terms. The present value of all finance payments (interest and principal) over the study period is calculated, together with the present value of any remaining principal at the end of the study period. If the loan is to be fully amortized over its life, the loan type (F(I,6)) is designated as 1. If interest, but no principal, is paid on the loan, with the entire principal paid at the end of the loan life, the loan type is designated as 2.

Up to 5 replacements to capital can be specified for each capital investment category. Each replacement can have its own depreciation schedule and resale value if specified. This does not affect the depreciation schedule for the capital investment category to which it is assigned.

All investments (including replacements) and operating-related costs are entered in base-period dollars, rather than in future-year dollars. Separate cost inflation factors can be entered for each cost category. (Replacement costs are inflated at the same rate as the capital investment category to which they are assigned.) In addition, for energy cost projections, different cost inflation factors can be used during different time intervals over the study period.

Table B-3 provides a list of input variables needed to run the program. Table B-4 gives some of the intermediate calculation variables used in the program. Table B-5 provides the correct format for entering the data into the program. Data is typically entered starting with line 9000.

In its simplest form, only one capital investment category with an investment cost and one operating cost need be entered, together with a study period length and discount rate. In such a case, all other data entries are made with zeroes (Ø). Specification of one or more capital investment categories (C2), one or more replacements (C(I,12)), one or more mortgage loans (F1), one or more non-annually recurring OM&R costs (M4), or one or more inflation-rate intervals (E(2,I)) requires that the corresponding number of entries be made in full for each.

Three methods of depreciation can be specified: (1) straight line, (2) declining balance, and (3) sum of digits. If depreciation is not used, the method is specified as Ø and no further depreciation data is needed. Specification of a depreciation rate must be made for the declining balance method. For example, specify 2 for a double (200%) declining balance method. For the straight-line or sum-of-digits methods enter Ø for the depreciation rate. Basic Internal Revenue Service (IRS) rules are used in computing annual depreciation. For the straight-line and sum-of-digits methods, salvage value in base-period dollars is deducted from the investment cost before setting up a depreciation schedule. Additional first year depreciation (as allowed by law) can be specified. The accelerated depreciation method automatically switches over to the straight-line method when the latter allows greater deductions than the former. The salvage value and life for depreciation purposes are specified separately from the actual expected resale value and useful life of a capital investment. Depreciation tax savings, like other tax credits, are discounted from the end of the year to which they apply.

Property taxes (other than for land) are estimated yearly using a constant rate of decline in asset value to reflect physical deterioration and technical obsolescence until the expected resale value is reached. These remaining asset values are in turn adjusted upwards to reflect inflation. Land value is adjusted only for inflation. The adjusted value is then multiplied by an assessment factor to arrive at an assessed value for tax computation purposes. A different assessment factor can be specified for each capital investment category; the assessment factor specified is also used for any capital replacement costs associated with a capital investment category. Property taxes are assumed to be paid at the beginning of the year.

Resale value (as a percentage of first cost, unadjusted for inflation) is specified for each capital investment and replacement as of the end of the study period (or at the time of disposal if less than the study period). A negative resale value can be used if disposal costs are expected to outweigh asset value. The resale value is adjusted for inflation using the inflation rate specified for the appropriate capital investment category. The resale value is meant to reflect a projection of actual asset value at the end of the study period (or useful life) rather than "salvage" value for depreciation computational purposes.

Capital gains tax liabilities are calculated on the resale value of the capital investments and replacements, adjusted for inflation. Taxes are computed at capital gains rates for the difference between the inflation-adjusted resale value and the basis (the original cost less accumulated depreciation) calculated by the straight-line depreciation method, regardless of the depreciation method used. If an alternative depreciation method is used (e.g., declining balance or sum of digits), the difference between the basis calculated using the straight-line method and the basis calculated using the alternative method is taxed as ordinary income. The program calculates no capital loss tax credit if the adjusted resale value is less than the basis. In general, good accounting practice would increase the depreciation rate in order to preclude such an anticipated capital loss.

LISTING OF TLCC COMPUTER PROGRAM

TLCC

```
10 REM: THIS PROGRAM PROVIDES A TOTAL LIFE-CYCLE COST ANALYSIS OF A
20 REM: BUILDING-RELATED PROJECT, CONSISTENT WITH THE PROPOSED ASTM
30 REM: STANDARD FOR LIFE-CYCLE COST ANALYSIS.  IT WAS DEVELOPED AT
40 REM: THE NATIONAL BUREAU OF STANDARDS BY STEVE PETERSEN IN 1980,
50 REM: AND LAST MODIFIED ON JUNE 11, 1980.
100 DIM C(10,13),F(3,9),X(4,40),U(10,5)
105 DIM D(2,40),E(4,5),Z(2,40)
106 DIM V(10,5)
110 DIM Y(10,5),R(10,5),L(10,5),S(10,5)
120 DIM A(10,5),B(10,5),I(4,5),P(4,5)
130 DIM W(25)
180 READ A$
185 READ I1,N1,T1,T2,T3,T4
190 READ C2
200 FOR I=1 TO C2
205 READ C$(I)
210 READ C(I,1),C(I,3)
214 IF C(I,3)=0 THEN 218
216 READ C(I,2),C(I,4),C(I,5),C(I,6)
218 FOR J=7 TO 12
220 READ C(I,J)
225 NEXT J
228 IF C(I,10)<999 THEN 233
229 IF C(I,12)=0 THEN 233
230 PRINT "WARNING: LAND CANNOT HAVE REPLACEMENTS. RUN TERMINATED"
231 STOP
233 IF C(I,10)>=C(I,2) THEN 235
234 PRINT "WARNING:DEPRECIATION LIFE OF "C$(I)" EXCEEDS ACTUAL LIFE."
235 IF C(I,10)>0 THEN 240
236 PRINT "EXPECTED LIFE OF "C$(I)" MUST > 0. RUN TERMINATED."
237 STOP
240 IF C(I,12)=0 THEN 290
250 FOR K=1 TO C(I,12)
260 READ Y(I,K),R(I,K),L(I,K),S(I,K),A(I,K),B(I,K)
263 IF A(I,K)>=L(I,K) THEN 266
264 PRINT "WARNING: DEPRECIATION LIFE OF REPLACEMENT "K" TO "C$(1)
265 PRINT "    EXCEEDS ACTUAL EXPECTED LIFE"
266 IF A(I,K) > 0 THEN 270
267 PRINT "EXPECTED LIFE OF REPLACEMENT"K" TO "C$(I)" MUST >0. RUN TERMINATED."
270 NEXT K
290 NEXT I
295 READ F1
300 FOR I=1 TO F1
310 FOR J=1 TO 6
320 READ F(I,J)
330 NEXT J
340 NEXT I
350 READ M1,M2
360 READ M4,M5
370 FOR J=1 TO M4
```

```
380 READ M(1,J),M(2,J)
382 IF M(1,J)<=N1 THEN 390
384 PRINT "WARNING: NON-RECURRING O&M OCCURS IN YEAR(S) BEYOND STUDY PERIOD"
390 NEXT J
395 READ N2
396 FOR I=1 TO N2
397 READ E(1,I),E(2,I+1)
400 FOR J=1 TO E(2,I+1)
410 READ I(I+1,J),P(I,J)
420 NEXT J
430 FOR J=1 TO E(2,I+1)-1
435 IF I(I+1,J+1)<N1+1 THEN 455
440 I(I,J)=N1+1-I(I+1,J)
445 E(2,I)=J
450 GOTO 480
455 I(I,J)=I(I+1,J+1)-I(I+1,J)
460 NEXT J
465 I(I,J+1)=N1+1-I(I+1,J+1)
470 E(2,I)=J+1
480 NEXT I
490 REM:ESTABLISH VARIABLESS FOR TAX PAYING STATUS AND LOAN TYP
500 T$(1)="PROFIT MAKING ENTERPRISE"
510 T$(2)= "TAX EXEMPT"
520 T$(3)= "PRIVATE RESIDENTIAL (TAX PAYING)"
530 L$(1)="AMORTIZED"
540 L$(2)="INTEREST ONLY"
1000 MAT W=ZER
1010 REM: COMPUTE INITIAL COST, W(1), AND INITIAL DOWN PAYMENT, W(2)
1015 F2=0
1020 FOR I=1 TO F1
1025 REM:COMPUTE TOTAL AMOUNT BORROWED LESS "POINTS" COST, F2
1030 F2=F2+F(I,1)*(1-F(I,5))
1040 NEXT I
1060 FOR I=1 TO C2
1070 W(1)=W(1)+C(I,1)
1080 NEXT I
1090 W(2)=W(1)-F2
1100 REM: COMPUTE LOAN PAYMENT PER TIME PERIOD FOR ITH LOAN, F(I,7)
1105 FOR I=1 TO F1
1110 IF F(I,6)=1 THEN 1120
1115 F(I,7)=F(I,3)/F(I,4)
1116 GOTO 1170
1120 IF F(I,3)<>0 THEN 1150
1130 F(I,7)=1/(F(I,2)*F(I,4))
1140 GOTO 1170
1150 F(I,7)=(F(I,3)/F(I,4))*(1+F(I,3)/F(I,4))^(F(I,2)*F(I,4))
1160 F(I,7)=F(I,7)/((1+F(I,3)/F(I,4))^(F(I,2)*F(I,4))-1)
1170 NEXT I
1180 REM: COMPUTE UPW FACTOR FOR ITH LOAN PAYMENT SCHEDULE, F(I,9)
1190 FOR I=1 TO F1
```

```
1200 REM: COMPUTE MIN:(STUDY PERIOD,LOAN LIFE) FOR ITH LOAN, F(I,8)
1210 F(I,8)=N1
1220 IF N1<=F(I,2) THEN 1240
1230 F(I,8)=F(I,2)
1240 IF I1=0 THEN 1280
1250 F(I,9)=(((1+I1/F(I,4))^(F(I,8)*F(I,4)))-1)
1260 F(I,9)=F(I,9)/(I1/F(I,4)*(1+I1/F(I,4))^(F(I,8)*F(I,4)))
1270 GOTO 1290
1280 F(I,9)=F(I,8)*F(I,4).
1290 REM: COMPUTE P.V. OF ALL LOAN PAYMENTS MADE DURING STUDY PERIOD, W(3)
1320 W(3)=W(3)+F(I,1)*F(I,7)*F(I,9)
1330 NEXT I
1400 REM: COMPUTE INTEREST PAID IN EACH YEAR X(2,J), CUMM INTEREST PAID AT
1401 REM:  YEAR J X(4,J),REMAINING PRINCIPAL AT END OF EACH YEAR X(1,J) AND
1402 REM:  ANY REMAINING PRINCIPAL W(4)
1404 FOR I=1 TO F1
1406 IF F(I,6)=1 THEN 1420
1408 W(4)=W(4)+F(I,1)/(1+I1)^F(I,8)
1410 FOR J=1 TO F(I,8)
1412 X(4,J)=F(I,1)*F(I,3)
1414 W(6)=W(6)+X(4,J)/(1+I1)^J
1416 NEXT J
1418 GOTO 1560
1420 REM
1430 X(1,0)=F(I,1)
1440 FOR J=1 TO F(I,2)
1450 X(2,J)=0
1460 X(3,0)=X(1,J-1)
1465 REM: X(3,K)=REMAINING PRINCIPAL AFTER EACH LOAN PAYMENT K IN YEAR J
1470 FOR K=1 TO F(I,4)
1480 X(3,K)=X(3,K-1)*(1+F(I,3)/F(I,4))-F(I,7)*F(I,1)
1490 X(2,J)=X(2,J)+X(3,K-1)*F(I,3)/F(I,4)
1500 NEXT K
1510 X(1,J)=X(3,F(I,4))
1530 X(4,J)=X(4,J)+X(2,J)
1535 W(6)=W(6)+X(4,J)/(1+I1)^J
1540 NEXT J
1550 W(4)=W(4)+X(1,N1)/(1+I1)^N1
1560 NEXT I
1570 W(5)=W(2)+W(3)+W(4)
1600 REM: COMPUTE ANNUAL DEPRECIATION ALLOWANCE FOR EACH FACTOR Z(2,J),
1601 REM: CUMM S.L. DEPRECIATION D(1,J) AND CUMM ACTUAL DEPRECIATION (D(2,J))
1610 MAT D=ZER
1620 FOR I=1 TO C2
1625 IF C(I,3)=0 THEN 1698
1630 D1=C(I,1)
1640 D2=C(I,2)
1650 D3=C(I,3)
1660 D4=C(I,4)
1670 D5=C(I,5)
```

```
1680 D6=C(I,6)
1690 GOSUB 4600
1692 FOR J=1 TO D2
1693 IF J>N1 THEN 1697
1694 W(7)=W(7)+Z(2,J)/(1+I1)^J
1695 D(2,I)=D(2,I)+Z(2,J)
1696 D(1,I)=D(1,I)+Z(1,J)
1697 NEXT J
1698 NEXT I
1700 FOR I=1 TO C2
1710 FOR K=1 TO C(I,12)
1720 W(10)=W(10)+R(I,K)*((1+C(I,7))/(1+I1))^(Y(I,K)-1)
1730 IF L(I,K)>0 THEN 1760
1740 PRINT "REPLACEMENT #"K" FOR FACTOR "C$(I)"SHOULD BE TREATED AS"
1741 PRINT "  REPAIR SINCE DEPRECIATION LIFE = 0"
1750 STOP
1760 D1=R(I,K)*(1+C(I,7))^(Y(I,K)-1)
1770 D2=L(I,K)
1780 D3=C(I,3)
1790 D4=C(I,4)
1800 D5=S(I,K)
1810 D6=C(I,6)
1820 GOSUB 4600
1840 FOR J=Y(I,K) TO Y(I,K)+L(I,K)-1
1850 IF J>N1 THEN 1890
1860 W(8)=W(8)+Z(2,J)/(1+I1)^J
1865 REM: U(I,K)=CUMM DEPRECIATION FOR KTH REPLACEMNT OF ITH FACTOR
1870 U(I,K)=U(I,K)+Z(2,J)
1875 V(I,K)=V(I,K)+Z(1,J)
1880 NEXT J
1890 NEXT K
1895 NEXT I
1900 W(9)=W(7)+W(8)
2200 REM: COMPUTE P.V. OF INVESTMENT TAX CREDIT FOR FACTORS,W(11)
2210 FOR I=1 TO C2
2220 W(11)=W(11)+C(I,9)*C(I,1)/(1+I1)
2222 FOR K=1 TO C(I,12)
2224 W(12)=W(12)+R(I,K)*C(I,9)*((1+C(I,7))/(1+I1))^Y(I,K)
2226 NEXT K
2230 NEXT I
2240 W(13)=W(11)+W(12)
2300 REM
2310 FOR I=1 TO C2
2320 REM: COMPUTE MIN (STUDY PERIOD, USEFUL LIFE)
2330 C(I,13)=N1
2340 IF C(I,10)>=N1 THEN 2360
2350 C(I,13)=C(I,10)
2360 W(14)=W(14)+C(I,1)*C(I,11)*((1+C(I,7))/(1+I1))^C(I,13)
2370 D7=C(I,1)*C(I,11)*(1+ C(I,7))^C(I,13)
2372 IF D7>=C(I,1)-D(1,I) THEN 2380
```

```
2373 IF D7>=C(I,1)-D(2,I) THEN 2385
2374 PRINT "WARNING: RESALE PRICE OF "C$(I)" IS LESS THAN "
2375 PRINT "  REMAINING BASIS.  DEPRECIATION RATE SHOULD BE INCREASED."
2376 PRINT "  CAPITAL LOSS NOT COMPUTED."
2377 GOTO 2400
2380 D6=(D7-(C(I,1)-D(1,I)))*T3+(D(2,I)-D(1,I))*T1
2381 GOTO 2390
2385 D6=(D7-(C(I,1)-D(2,I)))*T1
2390 W(17)=W(17)+D6/(1+I1)^C(I,13)
2400 REM
2410 FOR K=1 TO C(I,12)
2420 C(I,13)=N1
2430 IF A(I,K)+Y(I,K)-1 >=N1 THEN 2450
2440 C(I,13)=A(I,K)+Y(I,K)-1
2450 W(15)=W(15)+R(I,K)*B(I,K)*((1+C(I,7))/(1+I1))^C(I,13)
2460 D7=R(I,K)*B(I,K)*(1+C(I,7))^C(I,13)
2462 IF D7>=R(I,K)-V(I,K) THEN 2468
2463 IF D7>=R(I,K)-U(I,K) THEN 2475
2464 PRINT "WARNING: RESALE PRICE OF REPLACEMENT "K" TO "C$(I)
2465 PRINT "  IS LESS THAN THE REMAINING BASIS.  DEPRECIATION RATE SHOULD"
2466 PRINT "  BE INCREASED.  CAPITAL LOSS IS NOT COMPUTED."
2467 GOTO 2490
2468 D6=(D7-(R(I,K)-V(I,K)))*T3+(U(I,K)-V(I,K))*T1
2469 GOTO 2480
2475 D6=(D7-(R(I,K)-U(I,K)))*T1
2480 W(18)=W(18)+D6/(1+I1)^C(I,13)
2490 NEXT K
2500 NEXT I
2510 W(16)=W(14)+W(15)
2520 W(19)=W(17)+W(18)
3000 REM: COMPUTE P.V. OF RECURRING O&M
3010 IF M2=I1 THEN 3050
3020 M3=((1+M2)/(I1-M2))*(1-((1+M2)/(1+I1))^N1)
3030 GOTO 3060
3050 M3=N1
3060 W(20)=M1*M3
3100 REM: COMPUTE P.V. OF NON RECURRING O&M
3120 FOR J=1 TO M4
3130 W(21)=W(21)+M(2,J)*((1+M5)/(1+I1))^M(1,J)
3140 NEXT J
3200 REM: COMPUTE P.F. OF PROPERTY TAXES FOR FACTORS, W(22), AND
3201 REM:  REPLACEMENTS, W(23)
3210 FOR I=1 TO C2
3215 C(I,13)=N1
3216 IF C(I,10)>= N1 THEN 3220
3217 C(I,13)=C(I,10)
3220 FOR J=1 TO C(I,10)
3230 IF J>N1 THEN 3260
3231 IF C(I,10)<999 THEN 3235
3232 REM: COMPUTE PROPERTY TAX FOR LAND (NON-DECLINING REAL VALUE)
```

```
3233 W(22)=W(22)+C(I,1)*C(I,8)*T2*((1+C(I,7))/(1+I1))^(J-1)
3234 GOTO 3250
3235 REM D8=CUMM S.L. DEPRECIATION BASED ON ACTUAL LIFE AND ACTUAL RESALE VALUE
3240 D8=((C(I,1)-C(I,1)*C(I,11))/C(I,13))*(J-1)
3245 W(22)=W(22)+(C(I,1)-D8)*C(I,8)*T2*((1+C(I,7))/(1+I1))^(J-1)
3250 NEXT J
3260 REM
3270 FOR K=1 TO C(I,12)
3271 C(I,13)=A(I,K)
3272 IF Y(I,K)+A(I,K)-1<N1 THEN 3280
3273 C(I,13)=N1-Y(I,K)+1
3280 FOR J=Y(I,K) TO Y(I,K)+A(I,K)-1
3290 IF J>N1 THEN 3320
3300 D8=((R(I,K)-R(I,K)*B(I,K))/C(I,13))*(J-1)
3305 W(23)=W(23)+(R(I,K)-D8)*C(I,8)*T2*((1+C(I,7))/(1+I1))^(J-1)
3310 NEXT J
3320 NEXT K
3330 NEXT I
3340 W(24)=W(22)+W(23)
3400 REM: E(3,I)=UPW* FOR ITH ENERGY TYPE
3410 FOR I=1 TO N2
3420 E(3,I)=0
3430 FOR K=1 TO E(2,I)
3440 D9=1
3450 FOR J=0 TO K-1
3460 D9=(((1+P(I,J))/(1+I1))^I(I,J))*D9
3470 NEXT J
3480 IF I1=P(I,K) THEN 3530
3490 D8=(1+P(I,K))/(I1-P(I,K))
3500 D7=1-((1+P(I,K))/(1+I1))^I(I,K)
3510 E(3,I)=D9*D8*D7+E(3,I)
3520 GOTO 3540
3530 E(3,I)=E(3,I)+D9*I(I,K)
3540 NEXT K
3550 NEXT I
3600 REM:E(4,I)=P.V. OF ENERGY TYPE I
3610 REM: W(25)=P.V. OF ALL ENERGY EXPENDITURES
3620 FOR I=1 TO N2
3630 E(4,I)=E(1,I)*E(3,I)
3640 W(25)=W(25)+E(4,I)
3650 NEXT I
4590 GOTO 8000
4600 REM: SUBROUTINE TO CALCULATE DEPRECIATION ALLOWANCE
4630 IF D3<4 THEN 4660
4640 PRINT "DEPRECIATION TYPE FOR "C$(I)" IS MISSPECIIFIED"
4650 STOP
4660 IF D3=0 THEN 5050
4665 D7=D1*(1-D6)
4680 REM: STRAIGHT LINE METHOD
4690 FOR J=1 TO D2
```

```
4700 Z(1,J)=Z(2,J)=D7*(1-D5)/D2
4710 NEXT J
4720 ON D3 GOTO 5040,4730,4960
4730 REM: DECLINING BALANCE METHOD
4740 D9=0
4750 FOR J=1 TO D2
4760 Z(2,J)=D4/D2*(D7-D9)
4765 REM : Z(2,J)=DEPRECIATION ALLOWNACE FOR YEAR J
4770 IF D7-D9-Z(2,J)<=D7*D5 THEN 4910
4780 IF (D7*(1-D5)-D9)/(D2-J+1)>Z(2,J) THEN 4820
4790 D9=D9+Z(2,J)
4795 REM: D9=CUMM DEPRECIATION
4800 NEXT J
4810 GOTO 5040
4820 REM: SWITCH FROM DECLINING BALANCE TO STRAIGHT LINE
4830 J1=J
4840 D8=(D7*(1-D5)-D9)/(D2-J+1)
4850 FOR J=J1 TO D2
4860 Z(2,J)=D8
4890 NEXT J
4900 GOTO 5040
4910 REM: BASIS CANNOT FALL BELOW SALVAGE VALUE
4915 J1=J
4920 Z(2,J)=D7*(1-D5)-D9
4925 REM: D7*(1-D5) = MAX AMOUNT THAT CAN LEGALLY BE DEPRECIATED
4930 FOR J=J1 +1 TO D2
4940 Z(2,J)=0
4950 NEXT J
4955 GOTO 5040
4960 REM : SUM OF DIGITS METHOD
4970 D8=0
4980 FOR J=1 TO D2
4990 D8=D8+J
5000 NEXT J
5010 FOR J=1 TO D2
5020 Z(2,J)=(D7*(1-D5))*(D2-J+1)/D8
5030 NEXT J
5040 Z(2,1)=Z(2,1)+D1*D6
5050 RETURN
6000 REM
8000 FOR I=1 TO 5
8010 PRINT
8020 NEXT I
8030 PRINT USING 8600,
8040 PRINT
8050 PRINT USING 8610,
8055 PRINT
8060 PRINT USING 8620,A$
8070 B$=DAT$
8080 PRINT USING 8630, B$
```

```
8090 PRINT USING 8640, N1
8100 PRINT USING 8650, I1*100
8110 PRINT USING 8660, T$(T4)
8120 PRINT USING 8670, T1*100
8130 PRINT USING 8680, T3*100
8140 PRINT USING 8690, T2*100
8150 PRINT
8160 PRINT USING 8700,
8170 FOR I=1 TO C2
8180 PRINT USING 8710,C$(I),C(I,1)
8190 NEXT I
8200 PRINT
8210 PRINT USING 8720,
8220 FOR I=1 TO F1
8230 PRINT USING 8730,I,F(I,1),F(I,2),F(I,3)*100,F(I,5)*100,L$(F(I,6))
8240 NEXT I
8250 PRINT
8260 PRINT USING 8600
8270 PRINT
8275 PRINT USING 8735,
8276 PRINT
8280 PRINT USING 8740
8290 PRINT USING 8750,W(2)
8300 PRINT USING 8760,W(3)
8305 IF W(4)<5 THEN 8320
8310 PRINT USING 8770,W(4)
8320 PRINT USING 8780,W(10)
8330 PRINT USING 8790,W(16)
8340 T9=W(2)+W(3)+W(4)+W(10)-W(16)
8350 IF T4=3 THEN 8430
8360 PRINT USING 8800,T9
8370 PRINT USING 8810
8380 IF T4=2 THEN 8400
8390 PRINT USING 8820,W(9)*T1
8395 T9=T9-W(9)*T1
8400 PRINT USING 8830,W(6)*T1
8410 PRINT USING 8840,W(13)
8420 T9=T9-W(13)-W(6)*T1
8422 IF T4=2 THEN 8430
8423 IF W(19)>=0 THEN 8427
8424 W9=ABS(W(19))
8425 PRINT USING 8846,W9
8426 GOTO 8429
8427 PRINT USING 8845,W(19)
8429 T9=T9+W(19)
8430 PRINT USING 8850,T9
8440 PRINT
8450 PRINT USING 8860
8460 PRINT USING 8870,W(20)
8470 PRINT USING 8880,W(21)
```

```
8480 PRINT USING 8890,W(25)
8482 T8=W(20)+W(21)+W(25)
8485 IF T4=3 THEN 8560
8490 PRINT USING 8900,W(24)
8495 T8=T8+W(24)
8500 PRINT USING 8800,T8
8510 ON T4 GOTO 8520,8540
8520 T7=T1*T8
8530 GOTO 8550
8540 T7=T1*W(24)
8550 PRINT USING 8905,T7
8560 PRINTUSING 8910,T8-T7
8562 PRINT
8565 PRINT USING 8920,T9+T8-T7
8568 PRINT
8569 PRINT
8570 PRINT USING 8930
8571 PRINT
8573 IF I1=0 THEN 8579
8575 A=(I1*(1+I1)^N1)/(((1+I1)^N1)-1)
8576 GOTO 8580
8579 A=1/N1
8580 T6=A*T9
8585 T5=A*(T8-T7)
8590 PRINT USING 8940,T6
8592 PRINT USING 8950,T5
8595 PRINT USING 8960, T6+T5
8597 PRINT
8598 PRINT USING 8600
8600: * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
8610:                  TOTAL LIFE-CYCLE COST ANALYSIS
8620:                  PROJECT NAME: 'LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
8630:                  DATE OF ANALYSIS: 'LLLLLLLLLLLLLLLLLL
8640:                  STUDY PERIOD: ##  YEARS
8650:                  DISCOUNT RATE: ##.#%
8660:                  TAX STATUS: 'LLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
8670:                  INCOME TAX RATE: ##.#%
8680:                  CAPITAL GAINS TAX RATE: ##.#%
8690:                  PROPERTY TAX RATE: ##.#%
8700:              INVESTMENT CATEGORY          PURCHASE COST
8710:                'LLLLLLLLLLLLLLLLLL          $#########
8720:     FINANCING    AMOUNT    LIFE    INTEREST RATE    POINTS    TYPE
8730:       LOAN # $#########  ## YEARS      ##.##%       ##.##% 'CCCCCCCCCCCCC
8735:      I.  PRESENT-VALUE LIFE-CYCLE COST ANALYSIS
8740:          A.  PRESENT-VALUE INVESTMENT COSTS
8745:                                             $#######
8750:               INITIAL DOWN PAYMENT                    $########
8760:               MORTGAGE PAYMENTS                        ########
8770:               REMAINING PRINCIPAL                      ########
8780:               REPLACEMENTS TO CAPITAL                  ########
```

```
8790:                RESALE VALUE AT END OF STUDY           (########)
8800:                   SUBTOTAL                            $########
8810:                INCOME TAX ADJUSTMENTS
8820:                   TAX SAVINGS FROM DEPRECIATION       (########)
8830:                   TAX SAVINGS FROM INTEREST PAYMENTS  (########)
8840:                   INVESTMENT TAX CREDITS              (########)
8845:                   CAPITAL GAINS ON INVESTMENT RESALE   ########
8846:                   CAPITAL LOSS ON INVESTMENT RESALE   (########)
8850:                      NET PRESENT-VALUE INVESTMENT COST            $########
8860:            B.  PRESENT-VALUE OPERATING, MAINTENANCE AND REPAIR COSTS
8870:                ANNUAL RECURRING COSTS (NON-FUEL)      $########
8880:                NON-ANNUAL RECURRING COSTS              ########
8890:                FUEL COSTS                              ########
8900:                PROPERTY TAXES                          ########
8905:                TAX SAVINGS FROM OM&R                  (########)
8910:                      NET PRESENT-VALUE OM&R COSTS                 $########
8920:            C.  TOTAL PRESENT-VALUE LIFE-CYCLE COSTS                $########
8930:       II.  ANNUAL-VALUE LIFE-CYCLE COSTS
8940:            A.  ANNUAL-VALUE INVESTMENT COSTS                       $########
8950:            B.  ANNUAL-VALUE OM&R COSTS                              ########
8960:            C.  TOTAL ANNUAL-VALUE LIFE-CYCLE COSTS                 $########
9000 DATA "TEST PROBLEM"
9010 DATA .12,30
9020 DATA .46,.025,.28,1
9030 DATA 3
9040 DATA "BUILDING", 1000000
9050 DATA 1,25,0,0,0
9060 DATA .1,.75,0
9070 DATA 50,.5
9080 DATA 1
9090 DATA 20,25000,10,0
9095 DATA 20,0
9100 DATA "EQUIPMENT",100000
9110 DATA 1,10,0,0,.1
9120 DATA .1,.5,.1
9130 DATA 15,.1
9140 DATA 1
9150 DATA 16,100000,10,0
9160 DATA 15,.1
9170 DATA "LAND",100000
9180 DATA 0
9190 DATA .1,.8,0
9200 DATA 999,1.0
9210 DATA 0
9300 DATA 2
9310 DATA 900000,20,.12,12,0,1
9320 DATA 50000,5,.15,1,0,2
9400 DATA 50000,.1
9410 DATA 5,.1
9420 DATA 5,20000
```

TLCC CONTINUED

```
9430 DATA 10,10000
9440 DATA 15,20000
9450 DATA 20,10000
9460 DATA 25,20000
9500 DATA 2
9510 DATA 10000,3
9520 DATA 1,.12
9530 DATA 11,.10
9540 DATA 21,.08
9550 DATA 20000,2
9560 DATA 1,.12
9570 DATA 16,.08
9999 END
```

TABLE B-1 SAMPLE TLCC COMPUTER PROGRAM OUTPUT

* *

TOTAL LIFE-CYCLE COST ANALYSIS

PROJECT NAME: TEST PROBLEM
DATE OF ANALYSIS: WED 06/18/80
STUDY PERIOD: 30 YEARS
DISCOUNT RATE: 12.0%
TAX STATUS: PROFIT MAKING ENTERPRISE
INCOME TAX RATE: 46.0%
CAPITAL GAINS TAX RATE: 28.0%
PROPERTY TAX RATE: 2.5%

INVESTMENT CATEGORY	PURCHASE COST
BUILDING	$1000000
EQUIPMENT	$100000
LAND	$100000

FINANCING	AMOUNT	LIFE	INTEREST RATE	POINTS	TYPE
LOAN 1	$900000	20 YEARS	12.00%	0.00%	AMORTIZED
LOAN 2	$50000	5 YEARS	15.00%	0.00%	INTEREST ONLY

* *

I. PRESENT-VALUE LIFE-CYCLE COST ANALYSIS		
A. PRESENT-VALUE INVESTMENT COSTS		
INITIAL DOWN PAYMENT	$250000	
MORTGAGE PAYMENTS	927036	
REMAINING PRINCIPAL	28371	
REPLACEMENTS TO CAPITAL	94069	
RESALE VALUE AT END OF STUDY	(362911)	
SUBTOTAL	$936566	
INCOME TAX ADJUSTMENTS		
TAX SAVINGS FROM DEPRECIATION	(199590)	
TAX SAVINGS FROM INTEREST PAYMENTS	(320559)	
INVESTMENT TAX CREDITS	(16424)	
CAPITAL GAINS ON INVESTMENT RESALE	105822	
NET PRESENT-VALUE INVESTMENT COST		$505815
B. PRESENT-VALUE OPERATING, MAINTENANCE AND REPAIR COSTS		
ANNUAL RECURRING COSTS (NON-FUEL)	$1148332	
NON-ANNUAL RECURRING COSTS	61612	
FUEL COSTS	786479	
PROPERTY TAXES	391329	
SUBTOTAL	$2387752	
TAX SAVINGS FROM OM&R	(1098366)	
NET PRESENT-VALUE OM&R COSTS		$1289386
C. TOTAL PRESENT-VALUE LIFE-CYCLE COSTS		$1795201
II. ANNUAL-VALUE LIFE-CYCLE COSTS		
A. ANNUAL-VALUE INVESTMENT COSTS		$62794
B. ANNUAL-VALUE OM&R COSTS		160069
C. TOTAL ANNUAL-VALUE LIFE-CYCLE COSTS		$222863

* *

TABLE B-2 SAMPLE INPUT DATA FILE FOR TLCC COMPUTER PROGRAM

```
9000 DATA "TEST PROBLEM"
9010 DATA .12,30
9020 DATA .46,.025,.28,1
9030 DATA 3
9040 DATA "BUILDING", 1000000
9050 DATA 1,25,0,0,0
9060 DATA .1,.75,0
9070 DATA 50,.5
9080 DATA 1
9090 DATA 20,25000,10,0
9095 DATA 20,0
9100 DATA "EQUIPMENT",100000
9110 DATA 1,10,0,0,.1
9120 DATA .1,.5,.1
9130 DATA 15,.1
9140 DATA 1
9150 DATA 16,100000,10,0
9160 DATA 15,.1
9170 DATA "LAND",100000
9180 DATA 0
9190 DATA .1,.8,0
9200 DATA 999,1.0
9210 DATA 0
9300 DATA 2
9310 DATA 900000,20,.12,12,0,1
9320 DATA 50000,5,.15,1,0,2
9400 DATA 50000,.1
9410 DATA 5,.1
9420 DATA 5,20000
9430 DATA 10,10000
9440 DATA 15,20000
9450 DATA 20,10000
9460 DATA 25,20000
9500 DATA 2
9510 DATA 10000,3
9520 DATA 1,.12
9530 DATA 11,.10
9540 DATA 21,.08
9550 DATA 20000,2
9560 DATA 1,.12
9570 DATA 16,.08
9999 END
```

TABLE B-3 INPUT VARIABLES TO TLCC COMPUTER PROGRAM

VARIABLE	DESCRIPTION
A$	PROJECT TITLE
I1	DISCOUNT RATE
N1	STUDY PERIOD
T1	INCOME TAX RATE
T2	PROPERTY TAX RATE
T3	CAPITAL GAINS TAX RATE
T4	TAX STATUS
T4 = 1	PROFIT-MAKING ENTERPRISE
T4 = 2	TAX EXEMPT
T4 = 3	PRIVATE RESIDENTIAL
C2	TOTAL NUMBER OF INVESTMENT CATEGORIES
FOR EACH INVESTMENT CATEGORY (I = 1, 2,..., C2)	
C$(I)	NAME OF I^{th} INVESTMENT CATEGORY
C(I,1)	NOMINAL PURCHASE COST
C(I,2)	DEPRECIATION LIFE
C(I,3)	DEPRECIATION METHOD
C(I,3) = 0	NO DEPRECIATION
C(I,3) = 1	STRAIGHT LINE
C(I,3) = 2	ACCELERATED
C(I,3) = 3	SUM OF DIGITS
C(I,4)	ACCELERATION RATE (Ø if C(I,3)≠2)
C(I,5)	SALVAGE VALUE (FOR TAX PURPOSES)
C(I,6)	ADDITIONAL FIRST YEAR DEPRECIATION (% of C(I,1))
C(I,7)	COST INFLATION RATE
C(I,8)	FIRST YEAR ASSESSED VALUE FOR PROPERTY TAX PURPOSES (% of C(I,1))
C(I,9)	INVESTMENT TAX CREDIT (% of C(I,1))
C(I,10)	ACTUAL EXPECTED USEFUL LIFE (use 999 for land)
C(I,11)	ESTIMATED RESALE VALUE AT END OF USEFUL LIFE OR END OF STUDY PERIOD, WHICHEVER COMES FIRST (% of C(I,1), in Base Year Dollars)
C(I,12)	NUMBER OF REPLACEMENTS DURING STUDY PERIOD
FOR EACH CAPITAL REPLACEMENT (K = 1, 2, ..., C(I,12))	
Y(I,K)	YEAR OF REPLACEMENT
R(I,K)	COST OF REPLACEMENT (Base Year Dollars)
L(I,K)	DEPRECIATION LIFE OF REPLACEMENT
S(I,K)	SALVAGE VALUE (% of R(I,K)) FOR TAX PURPOSES
A(I,K)	ACTUAL EXPECTED USEFUL LIFE
B(I,K)	ESTIMATED RESALE VALUE AT MIN (END OF USEFUL LIFE, END OF STUDY PERIOD)
F1	NUMBER OF MORTGAGE LOANS
FOR EACH LOAN (I = 1, 2, ..., F1)	
F(I,1)	AMOUNT BORROWED
F(I,2)	LIFE OF LOAN (YEARS)
F(I,3)	INTEREST RATE (ANNUAL)
F(I,4)	NUMBER OF PAYMENTS PER YEAR
F(I,5)	"POINTS" (in % of Loan Amount)
F(I,6)	LOAN TYPE
F(I,6) = 1	FULLY AMORTIZED
F(I,6) = 2	INTERST ONLY, PRINCIPAL PAID AT END OF LOAN LIFE
M1	ANNUAL RECURRING OM&R COST (Base Year Dollars)
M2	INFLATION RATE FOR M1 (ANNUAL)
M4	NUMBER OF NON-ANNUALLY RECURRING OM&R COSTS
M5	INFLATION RATE FOR NON-ANNUALLY RECURRING OM&R COSTS

TABLE B-3 (Continued)

FOR EACH NON-ANNUALLY RECURRING OM&R COST (i = 1, 2, ..., M4)

M(1,J)	YEAR OF OCCURRENCE
M(2,J)	AMOUNT (Base Year Dollars)
N2	NUMBER OF ENERGY TYPES USED

FOR EACH FUEL TYPE USED (I = 1, 2, ..., N2)

E(1,I)	ANNUAL FUEL COST (Base Year Dollars)
E(2,I)	NUMBER OF DISCRETE FUEL INFLATION RATES

FOR EACH DISCRETE FUEL INFLATION RATE (I = 1, 2, ..., E(2,I)

I(I,J)	YEAR IN WHICH P(I,J) BEGINS
P(I,J)	FUEL INFLATION RATE IN J^{th} TIME PERIOD

TABLE B-4 INTERMEDIATE CALCULATION VARIABLES USED IN TLCC COMPUTER PROGRAM

W (1)	INITIAL COST OF ALL FACTORS
W (2)	INITIAL DOWN PAYMENT
W (3)	P.V. OF LOAN PAYMENTS
W (4)	P.V. OF PRINCIPAL REMAINING AT END OF STUDY PERIOD
W (5)	W(2) + W(3) + W(4)
W (6)	P.V. OF INTEREST PAID ON LOANS DURING STUDY PERIOD
W (7)	P.V. OF DEPRECIATION FOR INITIAL INVESTMENTS
W (8)	P.V. OF DEPRECIATION FOR REPLACEMENTS
W (9)	W(7) + W(8)
W(10)	P.V. OF ALL REPLACEMENT COSTS
W(11)	P.V. OF INVESTMENT TAX CREDITS FOR INITIAL INVESTMENTS
W(12)	P.V. OF INVESTMENT TAX CREDITS FOR REPLACEMENTS
W(13)	W(11) + W(12)
W(14)	P.V. OF RESALE VALUE OF INITIAL INVESTMENT
W(15)	P.V. OF RESALE VALUE OF REPLACEMENTS
W(16)	W(14) + W(15)
W(17)	P.V. OF CAPITAL GAINS TAX ON INITIAL INVESTMENTS
W(18)	P.V. OF CAPITAL GAINS TAX ON REPLACEMENTS
W(19)	W(17) + W(18)
W(20)	P.V. OF ANNUALLY RECURRING MAINTENANCE
W(21)	P.V. OF NON-ANNUALLY RECURRING MAINTENANCE
W(22)	P.V. OF PROPERTY TAXES PAID ON INITIAL INVESTMENT
W(23)	P.V. OF PROPERTY TAXES PAID ON REPLACEMENT
W(24)	W(22) + W(23)
W(25)	P.V. OF ENERGY COSTS

TABLE B-5 DATA FORMAT FOR TLCC COMPUTER PROGRAM

Repeat		Statement	Fields						Note
		DATA	A$						
		DATA	I1	N1					
		DATA	T1	T2	T3	T4			
		DATA	C2						
REPEAT (C2) TIMES		DATA	C$(I)	C(I,1)					
REPEAT (C2) TIMES		DATA	C(I,3)						
REPEAT (C2) TIMES		DATA	C(I,2)	C(I,4)	C(I,5)	C(I,6)			use this line only if C(I,3) ≠ 0
REPEAT (C2) TIMES		DATA	C(I,7)	C(I,8)	C(I,9)				
REPEAT (C2) TIMES		DATA	C(I,10)	C(I,11)					
REPEAT (C2) TIMES		DATA	C(I,12)						
REPEAT (C2) TIMES	Repeat (C(I,12)) Times	DATA	Y(I,K)	R(I,K)	L(I,K)	S(I,K)			use only if C(I,12) ≠ 0
REPEAT (C2) TIMES	Repeat (C(I,12)) Times	DATA	A(I,K)	B(I,K)					use only if C(I,12) ≠ 0
		DATA	F1						
REPEAT (F1) TIMES		DATA	F(I,1)	F(I,2)	F(I,3)	F(I,4)	F(I,5)	F(I,6)	use only if F1 ≠ 0
		DATA	M1	M2	M4	M5			
REPEAT (M4) TIMES			M(1,J)	(M2,J)					
			N2						
REPEAT (N2) TIMES			E(1,I)	E(2,I)					
REPEAT (N2) TIMES	Repeat (E(2,I)) Times		I(I,J)	P(I,J)					

APPENDIX C

TLCC EVALUATION FOR A SAMPLE INVESTMENT PROBLEM

Investor: Corporate Owner of an Existing Industrial Plant

Objective: To provide space heating for the plant at lowest cost.

Alternatives Considered:

(1) Continue use of existing oil-fired furnace using No. 2 fuel oil without modification of the system,

(2) Purchase and install a waste heat recovery system to the jacket of the plant exhaust stack to supplement the existing space heating furnace and reduce its consumption of fuel oil by 90%.

Level of TLCC Analysis: After Taxes, After Inflation

TABLE C-1 SAMPLE INVESTMENT PROBLEM: DATA AND ASSUMPTIONS

Time Horizon (Investor's Holding Period)[a]	7 years
Discount Rate	15%
Inflation Rate	8%
Investment Cost Data	
Purchase and Installation Price	$35,000
Down Payment	$3,500
Loan Interest Rate	12.5%
Loan Life	7 years
Yearly Loan Payment	$7,012
Asset Life	20 years
Depreciation (Straight-Line)	$1,750/year[b]
Loan Interest Payments	Deductible from Taxable Income
Resale Value at End of 7 Years[c]	$22,750 $(1 + .08)^7$
Recurring O&M (Non-fuel) Costs	
Existing Furnace[d]	$500
Waste Heat Recovery System	$200
O&M Costs	Deductible form Taxable Income
Energy Costs	
Fuel Consumption for Space Heating without Waste Heat Recovery	1,000 MBtu/year (1,055 GJ/year)
Fuel Consumption for Space Heating with Waste Heat Recovery	100 MBtu/year (106 GJ/year)
Base Year Fuel Price	$5.69/MBtu ($5.39/GJ)
Fuel Price Escalation Rate, Compounded Annually	12.%
Federal Corporate Tax Rates	46% income tax rate 28% capital gains rate
State Tax Rates	Not considered

[a] A relatively short time horizon was selected for this example to facilitate a year-by-year display of costs; however, short time horizons are not atypical of many business investment analyses.

[b] Based on straight-line depreciation, 20 year life, and a book value of $35,000.

[c] Salvage value is based on the remaining book value after seven years, adjusted for inflation over the seven year holding period.

[d] Non-fuel O&M costs for the existing furnace are assumed to be unchanged by addition of the waste heat recovery system.

The TLCC of each of the two alternatives over the seven year holding period is calculated and displayed in the series of tables that follow. Tables C-2 through C-4 give the year-by-year results for alternative 1; that is, continuing to use the existing oil-fired furnace without modification. Tables C-5 through C-10 give the results for alternative 2; that is, supplementing the existing system with a waste heat recovery system. (The TLCC's of the alternatives are then compared to determine the lowest cost option.)

By comparing tables C-4 and C-10, we can see that the fuel cost reductions from the waste heat recovery system more then offset its after-tax investment and other costs. Therefore, the waste heat recovery system has the lowest TLCC and is the preferred investment alternative on economic grounds.

TABLE C-2. ALTERNATIVE 1: FUEL COSTS WITHOUT ADDITION OF THE WASTE HEAT RECOVERY SYSTEM

(1) Year	(2) Base Period Fuel Price, $/MBtu	(3) Annual Fuel Requirement, MBtu	(4) Fuel Price Escalation Multiplier	(5) Annual Fuel Cost After Escalation (2)x(3)x(4)	(6) Corporate Income Tax Rate, %	(7) Tax Reduction Due to Fuel Cost Deductions (5)x(6)	(8) Annual Fuel Cost After Tax and Escalation, $ (5)-(7)	(9) SPW Factor	(10) PV of Annual Fuel Cost After Tax and Escalation, $ (8)x(9)
0	5.69								
1		1,000	$(1 + .12)^1$	6,373	46	$2,932	3,441	.8696	2,992
2		1,000	$(1 + .12)^2$	7,138	46	3,283	3,855	.7561	2,915
3		1,000	$(1 + .12)^3$	7,994	46	3,677	4,316	.6575	2,838
4		1,000	$(1 + .12)^4$	8,953	46	4,118	4,835	.5718	2,765
5		1,000	$(1 + .12)^5$	10,028	46	4,613	5,415	.4972	2,692
6		1,000	$(1 + .12)^6$	11,231	46	5,166	6,065	.4323	2,622
7		1,000	$(1 + .12)^7$	12,579	46	5,786	6,793	.3759	2,553
							Total PV Fuel Cost		$19,377

TABLE C-3. ALTERNATIVE 1: OPERATION AND MAINTENANCE COSTS WITHOUT ADDITION OF THE WASTE HEAT RECOVERY SYSTEM

(1) Year	(2) Base-Period O&M Cost, $	(3) Inflation Multiplier	(4) Annual O&M Cost Cost After Inflation, $ (2)x(3)	(5) Corporate Income Tax Rate, %	(6) Tax Reduction Due to O&M Cost Deductions, $ (4)x(5)	(7) Annual O&M Cost After Tax and Inflation, $ (4)-(6)	(8) SPW Factor	(9) PV of Annual O&M Cost After Tax and Inflation, $ (7)x(8)
0	500							
1		$(1 + .08)^1$	540	46	248	292	.8696	254
2		$(1 + .08)^2$	583	46	268	315	.7561	238
3		$(1 + .08)^3$	630	46	290	340	.6575	224
4		$(1 + .08)^4$	680	46	313	367	.5718	210
5		$(1 + .08)^5$	735	46	338	397	.4972	197
6		$(1 + .08)^6$	793	46	365	428	.4323	185
7		$(1 + .08)^7$	857	46	394	463	.3759	174
						Total PV O&M Cost		$1,482

TABLE C-4 ALTERNATIVE 1: TLCC OF CONTINUING USE OF THE EXISTING FURNACE WITHOUT ADDITION OF THE WASTE HEAT RECOVERY SYSTEM

(1) PV OF Fuel Costs, $	(2) PV of O&M, $	(3) TLCC, after taxes and inflation $ (1) + (2)
19,377	1,482	20,859

TABLE C-5. ALTERNATIVE 2: FUEL COSTS WITH THE WASTE HEAT RECOVERY SYSTEM

(1) Year	(2) Base Period Fuel Price, $/MBtu	(3) Annual Fuel Requirement MBtu	(4) Fuel Price Escalation Multiplier	(5) Annual Fuel Cost After Escalation, $ (2)x(3)x(4)	(6) Corporate Income Tax Rate, %	(7) Tax Reduction from Fuel Cost Deductions, $ (5)x(6)	(8) Annual Cost After Tax and Escalation, $ (5)-(7)	(9) SPW Factor	(10) PV of Annual Fuel Cost After Tax and Escalation, $ (8)x(9)
0	5.69								
1		100	$(1 + .12)^1$	637	46	293	344	.8696	299
2		100	$(1 + .12)^2$	714	46	328	386	.7561	292
3		100	$(1 + .12)^3$	799	46	368	431	.6575	283
4		100	$(1 + .12)^4$	895	46	412	483	.5718	276
5		100	$(1 + .12)^5$	1,003	46	461	542	.4972	269
6		100	$(1 + .12)^6$	1,123	46	517	606	.4323	262
7		100	$(1 + .12)^7$	1,258	46	579	679	.3759	255
							Total PV Fuel Costs		$1,936

TABLE C-6. ALTERNATIVE 2: PURCHASE AND INSTALLATION COST OF THE WASTE HEAT RECOVERY SYSTEM

(1) Year	(2) Down Payment, $	(3) Annual Loan Payment, $	(4) UPW Factor 15%, 7 years	(5) PV of Loan Payments, $ ($7,012 x 4.160)	(6) Interest Payments[a], $	(7) Corporate Income Tax Rate, %	(8) Tax Reductions From Interest Deductions, $ (6)x(7)	(9) SPW Factors	(10) PV of Tax Reductions, $ (8)x(9)	(11) PV of After Tax, After Inflation, Investment Financing (2)+(5)-(10)[b]
0	3,500	--	4,160	29,170	--	--	--	--	--	--
1	--	7,012	--	--	3,938	46	$1,811	.8696	1,575	--
2	--	7,012	--	--	3,553	46	1,634	.7561	1,235	--
3	--	7,012	--	--	3,121	46	1,436	.6575	944	--
4	--	7,012	--	--	2,634	46	1,212	.5718	693	--
5	--	7,012	--	--	2,087	46	960	.4972	477	--
6	--	7,012	--	--	1,472	46	677	.4323	293	--
7	--	7,012	--	--	779	46	358	.3759	135	--
Total PV Purchase and Installation:										
	$3,500	--	--	$29,170	--	--	--	--	5,352	27,318

[a] Interest in year 1, based on a yearly loan payment: ($35,000 - 3,500)(.125) = $3,938; Interest in year 2 = [$(35,000 - 3,500) - (7,012 - 3,938)](.125) = $3,553; etc.

[b] Derives from the total present values of columns 2, 5, and 10.

TABLE C-7. ALTERNATIVE 2: DEPRECIATION ALLOWANCES FOR THE WASTE HEAT RECOVERY SYSTEM

(1) Annual Depreciation[a], $	(2) Corporate Income Tax Rate, $	(3) Annual Tax Reduction Due to Depreciation Allowance, $ (1)x(2)	(4) UPW Factor, 15%, 7 years	(5) PV of Depreciation Allowance, $ (3) x (4)
1,750	46	805	4.160	3,349

[a] Based on straight-line depreciation method, 20 year life, and book value of $35,000.

TABLE C-8. ALTERNATIVE 2: RESALE VALUE, NET OF CAPITAL GAINS TAX, FOR THE WASTE HEAT RECOVERY SYSTEM

(1) Year	(2) Resale Value End of 7 Years[a], $	(3) Book Value End of 7 Years[b], $	(4) Capital Gains, $ (2)-(3)	(5) Capital Gains Tax Rate, %	(6) Capital Gains Tax, $ (4)x(5)	(7) Resale Value Net of Capital Gains, $ (2)-(6)	(8) SPW Factor	(9) PV of Resale Value, Net of Capital Gains, $ (7)x(8)
7	38,990	22,750	16,240	28	4,547	34,443	.3759	12,947

[a] Based on original system cost of $35,000, system deterioration prorated uniformly over 20 years, and appreciation at the rate of general price inflation.

[b] Based on the original book value of $35,000 and 7 years straight-line depreciation of $1,750 per year.

TABLE C-9. ALTERNATIVE 2: NON-FUEL OPERATION AND MAINTENANCE COSTS WITH ADDITION OF THE WASTE HEAT RECOVERY SYSTEM

(1) Year	(2) Base-Period O&M Cost[a], $	(3) Inflation Multiplier	(4) Annual O&M Cost After Inflation, $ (2)x(3)	(5) Corporate Income Tax Rate, %	(6) Tax Reduction Due to O&M Cost Deductions, $ (4)x(5)	(7) Annual O&M Cost After Tax and Inflation, $ (4)-(6)	(8) SPW Factor	(9) PV of Annual O&M Cost After Tax and Inflation, $ (7)x(8)
0	700							
1		$(1 + .08)^1$	756	46	348	408	.8696	$ 355
2		$(1 + .08)^2$	816	46	375	441	.7561	333
3		$(1 + .08)^3$	882	46	406	476	.6575	313
4		$(1 + .08)^4$	952	46	438	514	.5718	294
5		$(1 + .08)^5$	1,029	46	473	556	.4972	276
6		$(1 + .08)^6$	1,111	46	511	600	.4323	259
7		$(1 + .08)^7$	1,200	46	552	648	.3759	244
							Total PV O&M Cost	$2,074

[a] Includes base year O&M cost for existing system ($500) and waste heat recovery system ($200).

TABLE C-10. ALTERNATIVE 2: TLCC WITH ADDITION OF THE WASTE HEAT RECOVERY SYSTEM

(1) PV of Fuel Costs, $	(2) PV of O&M, $	(3) PV of Investment Costs, $	(4) PV of Tax Reductions Due to Depreciation Allowance, $	(5) PV of Resale, $	(6) TLCC, After Taxes and Inflation, $ (1) + (2) + (3) - (4) - (5)
1,936	2,074	27,318	3,349	12,947	15,032

APPENDIX D

SELECTED LCC REFERENCES

1. Smith, Gerald W. Engineering Economy (Ames, Iowa: Iowa State University Press, 1973).

2. Grant, E. L. and Ireson, W. G. Principles of Engineering Economy, 5th ed. (New York, New York: The Ronald Press Co., 1970).

3. Mishan, E. J. Cost-Benefit Analysis, Expanded ed. (New York, New York: Praeger Publishers, Inc., 1976).

4. Dasqupta, A. K. and Pearce, D. W. Cost-Benefit Analysis (New York, New York: Barnes and Noble, 1972).

5. Sassone, Peter G. and Schaffer, William A. Cost-Benefit Analysis; A Handbook (New York, New York: Academic Press, 1978).

6. American Telephone and Telegraph Company. Engineering Economy, 3rd ed. (New York, New York: McGraw Hill Book Company, 1977).

7. Ruegg, Rosalie T. Life-Cycle Costing Manual for the Federal Energy Management and Planning Programs, National Bureau of Standards Special Publication (In Press) 1980.

8. Kirk, Stephen J. "Life Cycle Costing: Increasingly Popular Route to Design Value," and "Life Cycle Costing, Taken Step by Step," Architectural Record (A two part article), December 1979 and January 1980.

9. Hausman, Jerry A. "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables," Bell Journal of Economics, Vol. 10, No. 1, Spring 1979.

10. Fisher, Gene H. Cost Considerations in Systems Analysis, R-490-ASD, The Rand Corporation (New York, New York: American Elsevier Publishing Co., 1971).

11. Park, William R. Cost Engineering Analysis (New York, New York: John Wiley and Sons, 1973).

12. Ruegg, Rosalie T., McConnaughey, John S., et. al. Life-Cycle Costing; A Guide for Selecting Energy Conservation Projects for Public Buildings, National Bureau of Standards Report BSS 113 (Washington, D.C.: U.S. Government Printing Office, SD Cat. No. 003-003-01980-1, 1978).

13. Marshall, Harold E. and Ruegg, Rosalie T. "Life-Cycle Costing Guide for Energy Conservation in Buildings, Energy Conservation through Building Design, ed. Donald Watson (New York, New York: Architectural Record Book, McGraw-Hill, 1979).

14. Simplified Energy Design Economics, ed. Forrest Wilson, National Bureau of Standards Special Publications 544 (Washington, D.C.: U.S. Government Printing Office, SD Cat. No. 003-003-02156-3, 1980).

NBS-114A (REV. 9-78)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 80-2040	2. Gov't. Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE RECOMMENDED PRACTICE FOR MEASURING LIFE-CYCLE COSTS OF BUILDINGS AND BUILDING SYSTEMS			5. Publication Date June 1980 6. Performing Organization Code
7. AUTHOR(S) Rosalie T. Ruegg, Stephen R. Petersen, and Harold E. Marshall			8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, DC 20234			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)* Same as item 9			13. Type of Report & Period Covered Final 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Rising prices of labor, material, and particularly energy have forced builders, architects, engineers, building owners and operators, and code writers to identify building designs and building systems that will be cost effective in the long run. This report describes how to measure the life-cycle costs of buildings and building systems. Life-cycle cost analysis, when applied to building decisions, provides an economic evaluation of the net dollar effect, over time, of purchasing, constructing/installing, maintaining, operating, repairing, and replacing buildings or building systems. This recommended practice for making life-cycle cost evaluations will assist the private and public building communities in making cost-effective decisions.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Benefit-cost analysis; buildings; building economics; building systems standard; cost; discounting; economic analysis; inflation; life-cycle cost; present worth analysis; recommended practice.

18. AVAILABILITY ☒ Unlimited	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PRINTED PAGES
☐ For Official Distribution. Do Not Release to NTIS	UNCLASSIFIED	75
☐ Order From Sup. of Doc., U.S. Government Printing Office, Washington, DC 20402, SD Stock No. SN003-003-	20. SECURITY CLASS (THIS PAGE)	22. Price
☒ Order From National Technical Information Service (NTIS), Springfield, VA. 22161	UNCLASSIFIED	$7.00

USCOMM-DC