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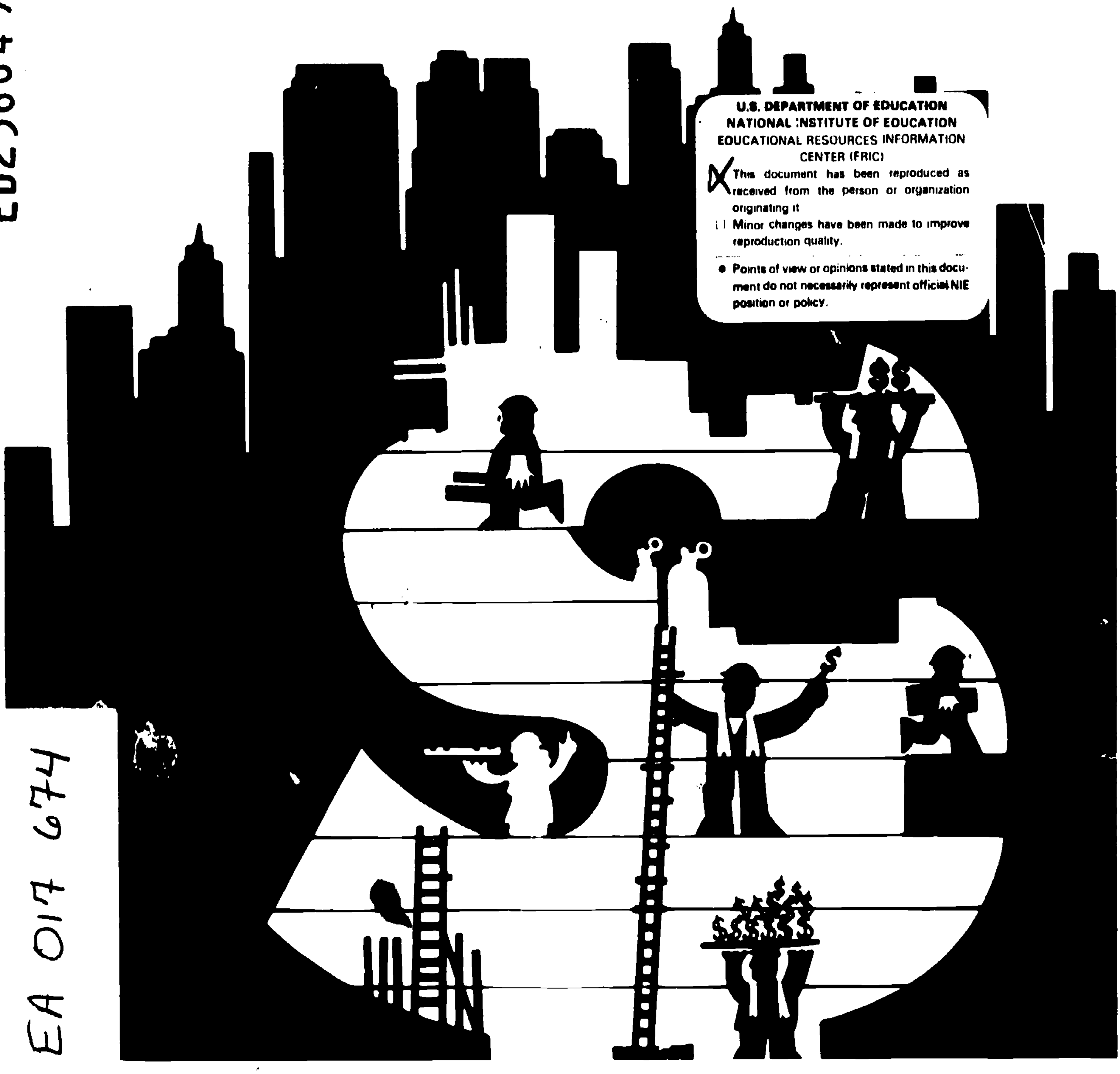
ABSTRACT

This workbook has been prepared for participants in the seminar, "Economic Evaluation of Building Design, Construction, Operation and Maintenance." It has two main functions: (1) to provide basic resource materials, references, and introductions to methods employed in the seminar; and (2) to provide instructional problems for solution by the participants. Specifically, it contains brief discussions of key elements in performing economic evaluations: discounting, escalation, establishing a study period, project selection techniques, and treatment of uncertainty; explanations of supporting analysis techniques--break-even analysis and replacement theory; and problems, worksheets, and solutions. Cross-references are given to related sections of a reference manual (NBS Handbook 135) and to case studies that illustrate the topics. The objectives of the seminar are to provide participants with a working knowledge of economic evaluation procedures for making building decisions, and to improve their decision-making abilities related to cost management and to the design and selection of buildings and building systems. Th seminar has been developed for building design engineers and architects, project planning and programming staff, managers of building programs, procurement officers and contract coordinators, building construction estimators, and building analysts. (Author)

SEMINAR WORKBOOK

Economic Evaluation of Building Design, Construction, Operation and Maintenance



U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NBS Technical Note 1195

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- Reactor Radiation

[1] Headquarters and Laboratories at Gaithersburg, MD, unless otherwise noted; mailing address Gaithersburg, MD 20899.
[2] Some divisions within the center are located at Boulder, CO 80303.
[3] Located at Boulder, CO, with some elements at Gaithersburg, MD.

NBS Technical
Note 1195

SEMINAR WORKBOOK

Economic Evaluation of Building Design, Construction, Operation and Maintenance

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Applied Mathematics
Operations Research Division
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Preface

This workbook has been prepared for participants in the seminar, "Economic Evaluation of Building Design, Construction, Operation and Maintenance." It has two main functions: (1) to provide basic resource materials, references, and introductions to methods employed in the seminar and (2) to provide instructional problems for solution by the participants.

Specifically, it contains brief discussions of key elements in performing economic evaluations: discounting, escalation, establishing a study period, project selection techniques, and treatment of uncertainty; explanations of supporting analysis techniques: break-even analysis and replacement theory; and problems, worksheets, and solutions. Cross references are given to related sections of a reference manual (NBS Handbook 135) and to case studies which illustrate the topics.

The objectives of the seminar are to provide participants with a working knowledge of economic evaluation procedures for making building decisions, and to improve their decision-making abilities related to cost management and to the design and selection of buildings and building systems.

The seminar has been developed for building design engineers and architects, project planning and programming staff, managers of building programs, procurement officers and contract coordinators, building construction estimators, and building analysts.

Acknowledgment

Appreciation is extended to the Public Building Service of the General Services Administration--particularly to Dave Eakin--for support in developing and field testing the seminar instructional materials. Appreciation is also given to the Federal Energy Management Program of the U.S. Department of Energy (DoE) for its contributions to the initial development of some of the energy conservation problems presented in this seminar. Earlier versions of these problems were prepared and presented by the National Bureau of Standards for DoE Life-Cycle Cost Workshops under the direction of Thomas Benson of the Federal Energy Management Program.

The author wishes to thank Dr. Harold Marshall, Leader of the Applied Economics Group of the National Bureau of Standards, for his invaluable assistance in developing the Workbook; Ms. Barbara Lippiatt, also of the Applied Economics Group, for her assistance in preparing the manuscript; and Ms. Laurene Linsenmayer for her patience and skill in typing the manuscript.

Contents

Sample
Seminar Agenda

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10:30	Class Problems in Discounting (Section 11)
11:00	LCC, NB, NS, BCR, SIR, IRR, and PB Analysis
12:00	Lunch
1:15	Pipe Insulation Retrofit Problem (Section 5)
2:15	Break
2:30	Programmable Time Clock Problem (Sections 10 and 11)
3:30	Review and Discussion
4:15	Adjournment

* References in parentheses are to sections of the workbook.

Day 2

8:45	Review of 1st Day Material - Questions and Answers
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10:30	Break
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2:15	Break
2:30	Team Critique of an Economic Evaluation Report (Section 15)
3:20	Group Discussion of Economic Evaluation for Building Decisions
3:45	Adjournment

Section 1

References

This section contains the following selected GSA and OMB documents pertaining to the economic evaluation of buildings and building systems:

(1) "Tech Aid on Life Cycle Costing" — Appendix 1-A of the GSA Design Handbook, which summarizes guidelines for construction-related economic decisions,

(2) OMB Circular No. A-94 revised, which pertains to discount rates to be used in evaluating time-distributed costs and benefits, and

(3) OMB Circular No. A-104, which pertains to comparative cost analysis for decisions to lease or purchase general purpose real property.

An additional document which is used extensively in this seminar is Life-Cycle Cost Manual for the Federal Energy Management Program, NBS Handbook 135 (Rev.). It is provided separately from the Workbook.

Relationship among referenced documents: Handbook 135 amplifies the methodology and procedures for life-cycle cost analysis of energy conservation projects established in Subpart A of Part 436 of Title 10 of the Code of Federal Regulations, entitled "Federal Energy Management and Planning Programs." This methodology was developed to be consistent with the guidelines on discounting in OMB Circular A-94, revised. However, an exception to Circular A-94's requirement for a 10 percent discount rate was provided by Section 405 of the Energy Security Act; the Act established a 7 percent discount rate for energy conservation projects. The GSA Tech Aid on Life-Cycle Costing, compiled for GSA staff and contractors is in turn consistent with Handbook 135.

OMB Circular A-104 presents the method of evaluating lease-buy decisions for acquisition of general purpose real property valued at $500,000 or more, and hence, concerns the method of securing the property in question, rather than the issue of whether or not having the property will be cost effective. This document is provided for the convenience of the user, because the decisions concerning project cost effectiveness and cost-effective acquisition of property generally go hand-in-hand.

1. FORMULAE

Unless otherwise directed in contract documents, construction related economic decisions shall employ a present value life cycle cost analysis in accord with the Code of Federal Regulations, Title 10, Part 436-A. In addition, and in summary, the following formulae and considerations shall apply. Formulae Notation:

PV = Present Value
FV = Future Real Value
TV = Today's Value
e = real growth escalation rate (the differential escalation rate which exists after removing the influence of general inflation. See 2.4 of this Appendix)
n = number of years to occurrence or the analysis period, as appropriate
d = real discount rate

1.1 Sunk Costs (those already spent or irrevocably committed) shall be ignored in LCC calculations. Such costs include:

- Study costs
- Construction work already started or completed
- Design costs where the expense is obligated by contract regardless of design solution.

1.2 Implementation (First) Costs shall be of estimated "today's value" and as such are by their nature in present value. See paragraph 2.3 of this Appendix. Such costs may include:

- Site acquisition
- Site survey/testing
- Design related fees
- Moving/relocation
- Demolition of existing (less salvage)
- Corrective Repair and Alteration to existing work
- Construction (with contingencies)
- Construction supervision

1.3 Non-recurring future costs will usually involve such needs as:

- Major replacement
- Non-annual maintenance and repair
- Implementation costs for major alterations to existing work including those cost elements described above for 1.2.

1.3.1 The present value of such costs can be treated by escalating a known "today's value" to its future value using a real growth escalation rate, then discounting that future value to a present value.

- Escalate the known today's value to the future value in constant dollars...$FV = TV\ (1+e)^n$, then discount that future value back to the present value. $PV = FV/(1+d)^n$. The term $(1/1+d)^n$ is known as the Single Present Worth (SPW) factor and is tabulated on page 114 of the referenced LCC Manual.

1.3.2 Or the combined procedure is represented by the equation $PV = TV\ (1+e/1+d)^n$. Note: If e = o, then $PV = TV(1/1+d)^n$

1.4 Uniform Annually Recurring Constant Dollar Costs may involve such costs as:

- Service contracts with an inflation adjustment clause
- Preventive maintenance
- Scheduled minor replacements
- Annually recurring costs which increase in price at the same rate as general inflation.

1.4.1 These can be converted to present value by the Uniform Present Worth (UPW) formula:

$$PV = TV\ (UPW), \quad \text{Where } UPW = \frac{(1+d)^n - 1}{d\ (1+d)^n},$$

The Uniform Present Worth (UPW) factor is tabulated on page 115 of the referenced LCC Manual.

1.4.2 This assumes that the cost of an activity will escalate with inflation and hence has a zero real growth rate.

1.5 Annually recurring costs which escalate in real value are usually associated with such costing elements as:

- Service/maintenance which involves increasing amounts of work and/or an escalation in cost different from general inflation.
- Fuel (utility) costs (see paragraph 1.6).
- Certain types of frequent replacement which escalate at a different rate than general inflation.

1.5.1 The Present Value relationship of such costs can be calculated by using the following modified version of the UPW formula (UPW*) which allows for cost escalation:

PV = TV (UPW*),

Where if e = d, UPW* = n
if e ≠ d, and e is constant over n, then

$$UPW^* = \frac{((1+e)/(1+d))^n - 1}{1 - (1+d)/(1+e)}$$

$$\text{or} = \left[\frac{1+e}{d-e}\right]\left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

NOTE: The 1980 ASHRAE Systems Handbook representation of this equation is incorrect (p. 45.4) and so noted in its errata.

1.6 Recurring fuel cost can be represented in present value by employing a modified Uniform Present Worth (UFW*) factor that takes into account multiple escalation rates. The UPW* factors are found in the CFR, Title 10, Part 436-A, shown tabularly in Tables B-1 thru 11 by Region, Billing Sector (e.g., commercial), Fuel Type, and analysis period. The formula to be applied is as follows:

PV = TV (UPW*)

1.6.1 Generally, the Today's Value (TV) of fuel costs should be calculated as the annual quantity of fuel times the actual local fuel pricing charged by the impacted utility at the beginning of the study period.

1.6.2 Electric demand charges should be assumed to escalate at the same rate as shown in Tables B-1 thru 11 for electricity consumption unless actual escalation rates for demand are provided by the local utility.

2. PROCEDURES AND APPROACH

2.1 When defining alternates for life cycle costing, an acceptable level of overall building service must be maintained for the analysis period. Costs which are common to all options may be ignored.

2.2 All design alternates shall be compared against a baseline reference option.

2.2.1 The baseline must represent all costs and actions necessary to support the impacted service functions over the entire analysis period for the lowest total installation cost of the considered options.

2.2.2 Where the existing conditions will form part of the baseline, there shall be those additional costs necessary to offer code compliance to impacted services, and all associated work identified in GSA Repair and Alteration Planning documents, and all costs necessary to ensure reliable operation.

2.2.3 The baseline must represent a logical evolution of building costs employing state-of-the-art design options.

2.2.4 Generally, the building system designs and guidance contained in this Design Management Handbook shall serve as input to the baseline for performance and policy requirements.

2.3 Unless directed otherwise in contract documents, all first costs of implementation shall be assumed to occur instantly, at the beginning of the analysis period. See paragraph 2.8 of this appendix.

The Code of Federal Regulations (CFR) Title 10, Part 436-A, presently speaks to a 10% adjustment to the initial investment for all energy conservation projects. Hence, only 90% of the initial investment costs are included in calculating the net benefit and the cost indices mentioned in Section 3.1 of this Appendix. This reduction allowance was provided in the LCC Rulemaking to compensate for external beneficial side effects associated with conservation measures; socio-economic, national security, etc. This factor shall be applied to all concepts which have been developed specifically to conserve energy (such as in energy studies).

However, the adjustment factor looses meaning when applied to new and retrofit projects where the compared design alternates involve energy usage but are not being pursued expressly to conserve energy. Here the 10% adjustment serves only to benefit the concept which has the highest dollar return, which may be more associated with non-energy cost avoidance such as repairs, maintenance, etc. Consequently, for all new construction projects and for projects not specifically developed to conserve energy, the 10% adjustment should be ignored, allowing the total investment cost to be applied in the analysis.

2.4 All future cost projections shall be established by escalating a known "today's value" with a real escalation rate: this will represent that cost in "constant dollars." That constant dollar future cost shall be discounted with a real discount rate to present value: In this process of discounting, future costs are expressed in "constant dollars."

When converting escalation projections which are actual cash flow rates (also referred to as budgetary or nominal rates) to an escalation rate in real terms (without inflation), the following formula applies:

$E = e + I + eI$, or $e = \left(\frac{1 + E}{1 + I}\right) - 1$

Where: E = budgetary escalation
e = real growth escalation
I = inflation rate

Hence, to convert a given budgetary projection of 15% to real terms, allowing for say 10% inflation, the real growth escalation would be: $e = ((1 + .15)/(1 + .10)) - 1$, for $e = 0.0454$ or 4.54%.

2.5 An exact accounting shall be made for those alternate and baseline investment and replacement costs directly associated with implementation and continued building service. However, to simplify the analysis, all recurring cost avoidance may be considered to be in relationship to the initial differences that exist between the alternate and the baseline: Hence, for simplicity, an expected future change in, say, a baseline's annual energy consumption may be ignored, allowing the consumption usage of the initial baseline condition to be assumed over the entire analysis period. An exact accounting of fluctuating recurring costs will be required only if so stated in contract documents.

2.6 The analysis period shall be as required to fully represent all major costs to the Government and as stated within the CFR, Title 10, Part 436-A.

2.6.1 All mutually exclusive options shall be considered over the same analysis period.

2.6.2 Where possible, the analysis period should be the smallest whole multiple of the service lives for the major systems involved in the analysis. (Example: With Option A the service life of 2 years is expected before replacement; with Option B the life of 3 years is anticipated; the smallest whole multiple of 6 would then be an appropriate analysis period.) Life expectancies of major equipment can best be obtained from manufacturers. Also, the ASHRAE Systems Handbook, page 45.2, has equipment life listings which may be appropriate.

2.6.3 Unless otherwise directed in design programming documents, the analysis period shall in no case exceed 25 years.

2.7 For those instances where either the baseline or alternate have service life beyond the analysis period, an allowance shall be provided for that associated residual service worth. This shall involve: (1) identifying the residual constant dollar value at the end of the analysis period, defined by the intercept of a straight line depreciation from the installed constant dollar cost to its end of service salvage value, and (2) discounting that residual constant dollar value to its present value.

2.8 Because of the design and construction process, the period between the identification of a retrofit option and its implementation may involve a lead time of several years. When comparing a retrofit option which has a multi-year lead time to a baseline case, the following applies to the treatment of costs impacted by the lead time.

2.8.1 All costs that must be incurred during the lead time, regardless of whether the retrofit option is adopoted, should be deemed sunk and excluded from the analysis of both the baseline case and the retrofit option.

2.8.2 All deferable lead time costs that are avoidable if the retrofit option is adopted, should be included as a cost for the baseline case but not for the retrofit option. To simplify this analysis, the lead time can be compressed and the avoidable costs for the baseline can be assumed to occur at the start of the analysis period as with the investment cost of the retrofit option: When doing so, however, all future planned year projections of investment and replacement cost occurrence must be adjusted to occur earlier in the analysis by the length of the lead time period.

2.8.3 For mutually exclusive options where lead time results in significant differences in cost advoidance, a more rigorous analysis shall be provided which reflects the lead time. This may require the discounting of investment and other costs to take into account their lead time.

3. ANALYSIS PRESENTATION

3.1 Indices: Unless otherwise noted, the following relationships shall be calculated for life cycle cost alternates.

3.1.1 For all life cycle cost analyses, calculate:

- Savings to Investment Ratio (SIR): The ratio of the present value savings of an alternate to its increase in present value implementation costs.
- Net Savings (NS): The difference in total life cycle cost between the baseline and a concept alternate.

3.1.2 For energy conservation retrofit projects, also calculate:

- Energy Savings to Investment Ratio (ESIR): The ratio of the annual source energy savings in 1,000 Btu's (MBTU) to the initial investment costs in dollars.
- Energy Cost Savings Ratio (ECSR): The ratio of the present value energy savings to the initial investment cost.

3.2 For each design option, the life cycle costing elements shall be summarized in the format as shown on the attached data sheet.

3.3 Detailed calculation cost back-up sheets may consist of the forms shown in the referenced LCC Manual or any other orderly format as agreed-to by GSA Reviewing Officials.

3.4 Computer representation of costs shall be acceptable only if provided with a manual example showing equivalency of calculation with one of the computerized solutions.

4. INTERPRETATION

4.1 Due to possible margins of error, where comparative economic analysis shows a difference less than 10 percent, the economic analysis may be considered indeterminate at the discretion of GSA Reviewing Officials.

4.2 Life Cycle Cost analysis may be subject to overriding qualitative considerations: e.g., occupancy impact, safety concerns, or problems of reliability.

references

originator OFFICE OF DESIGN AND CONSTRUCTION
DESIGN MANAGEMENT DIVISION
DESIGN PROGRAMS BRANCH

Building Name: ______________________ Building Number: ______
Project Name: ______________________ Project Number: ______
Concept Title: ______________________

Analysis Data: Period = ____ Years, Real Discount Rate = ____%, Date: __/__/__
Energy Data: Saved Fuel Type ________, Source Amount = z = ________ MBTU/YR.
Unit Fuel Cost ________, DOE Region ________, Sector ________

COST ELEMENTS	BASELINE	ALTERNATE	DIFFERENCE
a. Construction Cost	$	$	$
b. Contingencies (0.05 x a)	$	$	
c. Design Fee + Award Costs	$	$	
d. Construction Supervision	$	$	
e. Moving Costs	$	$	
f. Relocation Costs	$	$	
g. Initial Training Costs	$	$	
h. Other First Costs	$	$	
(1) SUBTOTAL (add above)	$	*$	w. $
i. TV Energy Cost/Year	$	$	
j. PV All Energy Costs	$	$	y. $
k. TV Maintenance Cost/Year	$	$	
l. PV All Maintenance Costs	$	$	
m. TV Service Cost/Year	$	$	
n. PV Service Costs	$	$	
(2) SUBTOTAL (j + l + n)	$	$	v. $
o. TV Future Replacements	$	$	
p. PV All Future Replacements	$	$	
q. TV Salvage	$	$	
r. PV Salvage	$	$	
s. Depreciated Residual Worth	$	$	
t. PV Residual Worth	$	$	
(3) SUBTOTAL (p − r or t)	$	$	x. $
TOTAL LIFE CYCLE COST (1)+(2)+(3)	$	$	u. $

Net Savings (NS) = u.
Savings to Investment Ratio (SIR) = v/(w + x) = ________.

* For Energy Conservation Projects, this value should be adjusted to be 10% less than estimated actual investment cost.

For Energy Conservation Projects:

Energy Savings to Investment Ratio = z/w = ________.
Energy Cost Savings Ratio = y/w = ________.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

March 27, 1972 BEST COPY AVAILABLE CIRCULAR NO. A-94
Revised

TO THE HEADS OF EXECUTIVE DEPARTMENTS AND ESTABLISHMENTS

SUBJECT: Discount rates to be used in evaluating time-distributed costs and benefits

1. Purpose. This Circular prescribes a standard discount rate to be used in evaluating the measurable costs and/or benefits of programs or projects when they are distributed over time.

2. Rescission. This Circular replaces and rescinds Office of Management and Budget (OMB) Circular No. A-94 dated June 26, 1969.

3. Scope.

a. This Circular applies to all agencies of the executive branch of the Federal Government except the U.S. Postal Service. The discount rate prescribed in this Circular applies to the evaluation of Government decisions concerning the initiation, renewal or expansion of all programs or projects, other than those specifically exempted below, for which the adoption is expected to commit the Government to a series of measurable costs extending over three or more years or which result in a series of benefits that extend three or more years beyond the inception date.

b. Specifically exempted from the scope of this Circular are decisions concerning water resource projects (guidance for which is the approved Water Resources Principles and Standards), the Government of the District of Columbia, and non-Federal recipients of Federal loans or grants.

c. The remaining exemptions derive from the secondary nature of the decisions involved; that is, how to acquire assets or proceed with a program after an affirmative decision to initiate, renew, or expand such a program using this Circular. Thus:

(1) This Circular would not apply to the evaluation of decisions concerning how to obtain the use of real property, such as by lease or purchase.

(2) This Circular would not apply to the evaluation of decisions concerning the acquisition of commercial-type services by Government or contractor operation, guidance for which is OMB Circular No. A-76;

(3) This Circular would not apply to the evaluation of decisions concerning how to select automatic data processing equipment, guidance for which is OMB Circular No. A-54 and OMB Bulletin No. 60-6.

d. The discount rates prescribed in this Circular are:

(1) Suggested for use in the internal planning documents of the agencies in the executive branch;

(2) Required for use in program analyses submitted to the Office of Management and Budget in support of legislative and budget programs.

This Circular does not supersede agency practices which are prescribed by or pursuant to law, Executive order, or other relevant Circulars. Agencies should evaluate their programs and projects in accordance with existing requirements and, in addition, summarize the present value costs and/or benefits using the discount rate prescribed in this Circular.

4. Definitions. Analytic documents submitted to the Office of Management and Budget should be based on the following concepts where relevant:

a. Expected annual cost means the expected annual dollar value (in constant dollars) of resources, goods, and services required to establish and carry out a program or project. Estimates of expected yearly costs will be based on established definitions and practices for program and project evaluation. However, all economic costs, including acquisition, possession, and operation costs, must be included whether or not actually paid by the Federal Government. Such costs not generally involving a direct Federal payment include imputed market values of public property and State and local property taxes foregone.

b. Expected annual benefit means the dollar value (in constant dollars) of goods and services expected to result from a program or project for each of the years it is in operation. Estimates of expected yearly benefits will be based on established definitions and practices developed by agencies for program and project evaluation.

c. Expected annual effects means an objective, non-monetary measure of program effects expected for each of the years a program or project is in operation. When dollar value cannot be placed on the effects of comparable programs or projects, an objective measure of effects may be available and useful to enable the comparison of alternative means of achieving specified objectives on the basis of their relative present value costs. These effects should be estimated for each year of the planning period and are not to be discounted.

d. Discount rate means the interest rate used in calculating the present value of expected yearly costs and benefits.

e. Discount factor means the factor for any specific discount rate which translates expected cost or benefit in any specific future year into its present value. The discount factor is equal to $1/(1+r)^t$, where r is the discount rate and t is the number of years since the date of initiation, renewal or expansion of a program or project.

f. Present value cost means each year's expected yearly cost multiplied by its discount factor and then summed over all years of the planning period.

g. Present value benefit means each year's expected yearly benefit multiplied by its discount factor and then summed over all years of the planning period.

h. Present value net benefit means the difference between present value benefit (item g) and present value cost (item f).

i. Benefit-cost ratio means present value benefit (item g) divided by present value cost (item f).

Attachment A contains an example that illustrates calculation of the present value information.

5. Treatment of inflation. All estimates of the costs and benefits for each year of the planning period should be made in constant dollars; i.e., in terms of the general purchasing power of the dollar at the time of decision. Estimates may reflect changes in the relative prices of cost and/or benefit components, where there is a reasonable basis for estimating such changes, but should not include any forecasted change in the general price level during the planning period.

6. Treatment of uncertainty. Actual costs and benefits in future years are likely to differ from those expected at the time of decision. For those cases for which there is a reasonable basis to estimate the variability of future costs and benefits, the sensitivity of proposed programs and projects to this variability should be evaluated.

The expected annual costs and benefits (or effects) should be supplemented with estimates of minimum and maximum values. Present value cost and benefits should be calculated for each of these estimates. The probability that each of the possible cost and benefit estimates may be realized should also be discussed, even when there is no basis for a precise quantitative estimate. Uncertainty of the cost and benefit (or effects) estimates should be treated explicitly, as described above. The prescribed discount rate should be used to evaluate all alternatives. Specifically, the evaluations should not use different discount rates to reflect the relative uncertainty of the alternatives.

7. Discount rate policy. The discount rates to be used for evaluations of programs and projects subject to the guidance of this Circular are as follows:

a. A rate of 10 percent; and, where relevant,

b. Any other rate prescribed by or pursuant to law, Executive order, or other relevant Circulars.

The prescribed discount rate of 10 percent represents an estimate of the average rate of return on private investment, before taxes and after inflation.

To assist in calculation, Attachment B contains discount factors for the discount rate of 10.0 percent for each of the years from one to fifty.

8. Interpretation. Questions concerning interpretation of this Circular should be addressed to the Assistant Director for Evaluation, Office of Management and Budget (395-3614).

GEORGE P. SHULTZ
DIRECTOR

Attachments

ATTACHMENT A
Circular No. A-94
Revised

SAMPLE FORMAT FOR DISCOUNTING DEFERRED COSTS AND BENEFITS

Assume a ten-year program which will commit the Government to the stream of expenditures appearing in column (2) of the table below and which will result in a series of benefits appearing in column (3). The discount factor for a 10 percent discount rate is presented in column (4). Present value cost for each of the ten years is calculated by multiplying column (2) by column (4); present value benefit for each of the ten years is calculated by multiplying column (3) by column (4). Present value costs and benefits are presented in columns (5) and (6), respectively.

Year since initiation, renewal or expansion (1)	Expected yearly cost (2)	Expected yearly benefit (3)	Discount factor for 10 percent (4)	Present value cost [Col. (2) x Col. (4)] (5)	Present value benefit [Col. (3) x Col. (4)] (6)
1	$10	$0	0.909	$9.1	$0.0
2	20	0	0.826	16.5	0.0
3	30	5	0.751	22.5	3.8
4	30	10	0.683	20.5	6.8
5	20	30	0.621	12.4	18.6
6	10	40	0.564	5.6	22.6
7	5	40	0.513	2.6	20.5
8	5	40	0.467	2.3	18.7
9	5	40	0.424	2.1	17.0
10	5	25	0.386	1.9	9.7
				$95.5	$117.7

The sum of column (5) is present value cost: $95.5
The sum of column (6) is present value benefit: $117.7

Present value net benefit is the difference between present value total benefit and present value total cost:
$117.7 - $95.5 = $22.2.

The benefit-cost ratio is 117.7/95.5 = 1.23.

NOTE: For more difficult discounting problems, a recommended reference is Principles of Engineering Economy, by Eugene L. Grant and W. G. Ireson, Ronald Press Company, 1960.

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ATTACHMENT B
Circular No. A-94
Revised

DISCOUNT FACTORS

Year since initiation, renewal or expansion	Discount factors*	Year since initiation, renewal or expansion	Discount factors*
1	0.909091	26	0.083905
2	0.826446	27	0.076278
3	0.751315	28	0.069343
4	0.683013	29	0.063039
5	0.620921	30	0.057309
6	0.564474	31	0.052099
7	0.513158	32	0.047362
8	0.466507	33	0.043057
9	0.424098	34	0.039143
10	0.385543	35	0.035584
11	0.350494	36	0.032349
12	0.318631	37	0.029408
13	0.289664	38	0.026735
14	0.263331	39	0.024304
15	0.239392	40	0.022095
16	0.217629	41	0.020086
17	0.197845	42	0.018260
18	0.179859	43	0.016600
19	0.163508	44	0.015091
20	0.148644	45	0.013719
21	0.135131	46	0.012472
22	0.122846	47	0.011338
23	0.111678	48	0.010307
24	0.101526	49	0.009370
25	0.092296	50	0.008519

*The discount factors presented in the table above implicitly assume end-of-year lump-sum costs and returns. When costs and returns occur in a steady stream, applying mid-year discount factors may be more appropriate. Present value cost and benefit computed from this table can be converted to a mid-year discounting basis by multiplying them by the factor 1.048809.

For example, if the present value cost of a series of annual expenditures computed from the above table is $1,200.00, the present value cost on a mid-year discounting basis is $1,200.00 x 1.048809 or $1,258.57.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

June 14, 1972 CIRCULAR NO. A-104

TO THE HEADS OF EXECUTIVE DEPARTMENTS AND ESTABLISHMENTS

SUBJECT: Comparative cost analysis for decisions to lease or purchase general purpose real property

1. Purpose. This Circular prescribes the economic basis for determining whether general purpose real property to be acquired for Government programs should be leased or purchased.

2. Scope.

a. The economic analysis prescribed in this Circular applies to the acquisition of general purpose real property such as office buildings, warehouses, and associated land for which estimated land and construction costs or market value is $500,000 or more.

b. The Circular does not preclude non-economic considerations, such as historic values, special conditions applying to overseas property, restricted access, and statutory requirements.

c. Analyses and decisions made under the guidance of this Circular should be based upon maximum agency use of long-term lease authority that may be requested of the General Services Administration as provided by the Federal Property and Administrative Services Act (40 USC 486(d), 490(h)(1) and Federal Property Management Regulations (101-18.107b)

3. Applicability.

a. This Circular applies to all agencies of the executive branch of the Federal Government except the United States Postal Service. It does not apply to the Government of the District of Columbia, or to non-Federal recipients of Federal loans or grants.

b. This Circular does not supersede agency practices concerning the acquisition or use of general purpose real property which are prescribed by or pursuant to law, Executive order, or other Circulars except for those portions of paragraph 6, Circular No. A-76, Revised, dated August 30, 1967, that apply to the determination of minimum cost lease-or-purchase alternatives.

c. This Circular does not preclude consideration of undiscounted cash flows for budgetary or other purposes. However, undiscounted cash flow analysis will not be the basis for identifying the most economic of lease-or-purchase alternatives.

d. The guidelines in this Circular are suggested for use in the internal planning documents of the agencies in the executive branch and required for use in all prospectuses, proposed legislation, budget justifications or other proposals submitted to the Office of Management and Budget and the Congress.

4. General requirements for analysis. The analysis of lease-or-purchase alternatives should be based on the following guidelines:

a. All economic costs incurred as a result of Federal acquisition of property must be included whether or not actually paid by the Federal Government. Such costs not generally involving a direct Federal payment include imputed market values of public property, State and local property taxes, and imputed insurance premiums.

b. The costs that will occur in each year of the period of analysis must be estimated in constant dollars (i.e., effects of inflation excluded) in terms of the general price level at the time of acquisition.

c. Acquisition alternatives will be compared on the basis of the expected time period of stable program use of the property. If such period is greater than the contract term permitted under authority for long-term leasing, the analysis should assume renewal of the lease at the last constant dollar payment.

d. Cost projections may be changed over the period of analysis to reflect only real changes in costs due to changes in amounts of services or their prices relative to the general price level--for example, an increase in amount of repair and improvements at prices in effect at the beginning of the period of analysis or an increase in the relative price of these services.

e. The present values of alternative cost projections over the relevant time period will be the basis for determining the most economic choice.

f. The discount rate applied to cost projections to determine present value will be seven percent. This rate represents an estimate of the internal rate of return on general purpose real property leased from the private sector, exclusive of property taxes and expected inflation. This rate is influenced by IRS tax treatment of real property and by separate handling of property taxes in this Circular; this rate is specific to lease-or-purchase decisions and is <u>not</u> comparable to before tax rates of return that the Office of Management and Budget specified in Circular No. A-94, Revised. The Office of Management and Budget will periodically review this estimate based upon the above criteria and will revise the rate as necessary.

5. <u>Costs to be included</u>. Constant dollar cost projections will include the following, adjusted as necessary to insure valid comparisons:

a. <u>Federal purchase alternative</u>.

(1) Purchase costs (include all construction, installation, site, design, management, and other costs associated with the acquisition of the asset and its preparation for use);

(2) Repair and improvement;

(3) Operation and maintenance;

(4) Imputed property taxes (exclude consideration of foreign taxes on overseas acquisitions unless actually paid);

(5) Imputed insurance premiums; and

(6) Cost offset: residual value at end of period.

b. <u>Lease alternative</u>.

(1) Lease payments;

(2) Repair and improvement (if not included in lease payments); and

(3) Operation and maintenance (if not included in lease payments).

c. Lease-purchase (or purchase-contract) alternative.

(1) Lease payments;

(2) Repair and improvement (after purchase or if not included in lease payments prior to purchase);

(3) Operation and maintenance (after purchase or if not included in payments prior to purchase);

(4) Purchase costs (when acquired) less applicable credit for previous payments;

(5) Imputed property taxes (after purchase or if not included in payments prior to purchase);

(6) Imputed insurance premiums (after purchase); and

(7) Cost offset (after purchase): residual value at end of period.

6. Costs that may be excluded. Some costs may be excluded from each of the alternative cost projections if they are estimated to be the same for all alternatives or too small to affect the economic choice among the alternatives under consideration; for example, such conditions may exist for:

a. Repair and improvement costs;

b. Operation and maintenance costs;

c. Property taxes; and

d. Insurance premiums.

7. Estimating certain costs. Potential problems of estimating certain costs should be resolved as follows:

a. Purchase costs. Determine market value for property that is already owned, donated, or acquired by condemnation.

b. Imputed property taxes.

(1) Determine the property tax rate for comparable property in the intended locality. If there is no basis by which to estimate future changes in tax rates and assessed (taxable) value, the first-year rate and assessed value can be applied to all years.

(2) Multiply the assessed value by the tax rate to determine the annual charge.

(3) As an alternative to the procedure of section 7.b(1)-(2) above, obtain an estimate of the local effective property taxes from the Building Owners and Managers Association's Regional Exchange Reports. If there is no basis for estimating future property taxes, the first-year rate can be applied to all years.

c. Imputed insurance premiums. Determine local estimates of standard, commercial coverage for like property from the Building Owners and Managers Association's Regional Exchange Reports.

d. Annual lease payments.

(1) Determine annual lease payments for comparable property and terms of lease in the intended locality at the time of proposed acquisition.

(2) When estimates of lease payments are based on actual lease contracts on comparable property, they should be adjusted to exclude the expected inflation for the period to first renewal, as described in Attachment A.

e. Cost offset: residual value at end of period.

(1) The objective is to predict the market value of the property at the end of the time period under consideration, excluding inflation.

(2) Residual values of property are determined by applying a method that best approximates the historically observed changes in market values experienced by the Government. The residual value of the property is obtained by adding the results of a decrease in the constant dollar market value of the building and an increase in the constant dollar market value of the site. To approximate the residual value of the building, a decay and obsolescence rate of 1.7 percent should be applied to each year's remaining constant dollar market value. To approximate the residual value of the site, the constant dollar market value should be increased by 1.5 percent each year. To assist in calculation, Attachment B contains building decay and obsolescence factors of 1.7 percent and site appreciation factors of 1.5 percent compounded for each of the years 1 to 30.

(3) Whenever possible, the residual value of the property should be adjusted to incorporate the current

market value for comparable property in similar locales for similar commercial property whose age is approximately equal to the period of analysis.

8. Present value calculations and format for comparisons.

a. Calculation of present values of the alternative cost projections will be performed in accordance with established discounting procedures, using either continuous or end-of-year discount factors.

b. Attachment C illustrates the method to be used in developing the present value comparisons.

c. Attachment D illustrates the required format for the comparative analysis of lease-or-purchase alternatives presented in prospectuses, proposed legislation, budget justifications, or other proposals for submission to OMB. All assumptions and basic cost data must be explicitly provided in the materials presented.

d. As required for particular activities, the Office of Management and Budget may request additional, special analyses and information and may change the requirements for reports to the OMB and to Congress.

CASPAR W. WEINBERGER
DIRECTOR

Attachments

ILLUSTRATION

PRESENT VALUE CONSTANT DOLLAR ANNUAL PAYMENT CALCULATIONS

To determine the present value constant dollar annual payments, where, for example,

- the date of initial acquisition is January 1972;
- the initial period of level payments = n = 20 years;
- the annual payment is $1,128,000 for 250,000 net square feet; and
- the payments are made at the end of the year,

calculate the average annual rate of inflation during the past n years.

The average inflation rate is found by (1) dividing the consumer price index at the beginning of the contract period (See the Economic Report of the President, February 1972, Table B-45, p. 247 for consumer price indexes.) by the consumer price index n years ago, and (2) comparing this result to the compound interest factors for n years. In this example, the consumer price index for 1971, 121.3 is divided by the consumer price index for 1951, 77.8 yielding 1.56. According to compound interest tables, the rate which would yield 1.56 in 20 years is approximately 2.2 percent.

Then, apply the determined constant dollar price deflator to each annual payment.

In this example, each annual current dollar payment of $1,128,000 must be multiplied by the appropriate constant dollar price deflator at 2.2% per year.

Finally, multiply each constant dollar annual payment by the appropriate 7 percent present value discount factor.

Year	Current dollar payment	Constant dollar price deflator @ 2.2%	Constant dollar payment	7% present value discount factor	Present value
1	1,128,000	.978	1,103,184	.935	1,031,477
2		.957	1,079,496	.873	942,400
3		.937	1,056,936	.816	862,460
4		.917	1,034,376	.763	789,229
5		.897	1,011,816	.713	721,425
6		.878	990,384	.666	659,596
7		.859	968,952	.623	603,657
8		.840	947,520	.582	551,457
9		.822	927,216	.544	504,406
10		.804	906,912	.508	460,711
11		.787	887,736	.475	421,675
12		.770	868,560	.444	385,641
13		.754	850,512	.415	352,962
14		.737	831,336	.388	322,558
15		.722	814,416	.362	294,819
16		.706	796,368	.339	269,969
17		.691	779,448	.317	247,085
18		.676	762,528	.296	225,708
19		.661	745,608	.277	206,533
20	1,128,000	.647	729,816	.258	188,293
					10,042,061

BUILDING DECAY-OBSOLESCENCE AND SITE APPRECIATION

Period of Analysis	Building Decay-Obsolescence Factors*	Site Appreciation Factors*
1	0.98300	1.01500
2	0.96629	1.03023
3	0.94986	1.04568
4	0.93371	1.06136
5	0.91784	1.07728
6	0.90224	1.09344
7	0.88690	1.10984
8	0.87182	1.12649
9	0.85700	1.14339
10	0.84243	1.16054
11	0.82811	1.17795
12	0.81403	1.19562
13	0.80019	1.21355
14	0.78659	1.23176
15	0.77322	1.25023
16	0.76007	1.26899
17	0.74715	1.28802
18	0.73445	1.30734
19	0.72197	1.32695
20	0.70969	1.34686
21	0.69763	1.36706
22	0.68577	1.38756
23	0.67411	1.40838
24	0.66265	1.42950
25	0.65139	1.45095
26	0.64031	1.47271
27	0.62943	1.49480
28	0.61873	1.51722
29	0.60821	1.53998
30	0.59787	1.56308

*The factors presented in the table above implicitly assume end-of-year building decay-obsolescence and site appreciation changes.

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PRESENT VALUE PURCHASE COST CALCULATIONS

[Federal Office Building, City, State]

Year	Constant Dollars (in thousands)				Present Value (in thousands)				
	Improvements, site a/	Repair and improvement	Property taxes	Residual value	7% discount factor	Improvements, site a/	Repair and improvement	Property taxes	Residual value
0	11,850	-	-		1.000	11,850			
1		48	200		.935		45	187	
2		48	200		.873		42	175	
3		48	200		.816		39	163	
4		48	200		.763		37	153	
5		48	200		.713		34	143	
6		80	200		.666		53	133	
7		80	200		.623		50	125	
8		80	200		.582		47	116	
9		80	200		.544		44	109	
10		80	200		.508		41	102	
11		144	200		.475		68	95	
12		144	200		.444		64	89	
13		144	200		.415		60	83	
14		144	200		.388		56	78	
15		144	200		.362		52	72	
16		144	200		.339		49	68	
17		144	200		.317		46	63	
18		144	200		.296		43	59	
19		144	200		.277		40	55	
20		144	200	9,270b/	.258		37	52	2,392
					Total Present Value	11,850	947	2,120	2,392

a/ For simplicity improvements (design and construction) costs of $10,500,000 and site costs of $1,350,000 are assumed to be paid at the start of year 1. All other costs shown assume payment at the end of the year specified.

b/ This figure represents the remaining value of the building which declines at 1.7 percent per year ($7,552,000) and the remaining value of the site which appreciates at 1.5 percent per year ($1,818,000).

ATTACHMENT C
Circular No. A-104

ATTACHMENT D
Circular No. A-104

ILLUSTRATION

PRESENT VALUE COST SUMMARIES FOR ALTERNATIVE METHODS OF ACQUISITION

[Federal Office Building, City, State]

(In thousands of dollars)

Item	20 years; 7%
PURCHASE:*	
Improvements	10,500
Site	1,350
Repair and improvement	947
Property taxes	2,120
Subtotal	14,917
Less residual value	2,392
Total	12,525
LEASE:*	
Total annual payments**	10,042
LEASE-PURCHASE (or PURCHASE-CONTRACT)*	
Annual payments until purchase***	8,845
Purchase cost less credit	3,556
Repair and improvement (after purchase) ..	515
Property taxes (after purchase)	714
Subtotal	13,630
Less residual value	2,392
Total	11,238

*Operation and maintenance costs are borne by the Government and are assumed to be identical for all three acquisition methods. Therefore, they are omitted in this comparison. Imputed insurance premiums are estimated to be negligible relative to other costs and therefore omitted.

**Annual lease payments in constant dollars are calculated. Then, each constant dollar lease payment is discounted at 7 percent (See Attachment A).

***Annual lease-purchase (or purchase-contract) payments of $1,400 + purchase of $21,000 (15 years annual payments) less credit of $14,000. The annual payments in constant dollars are calculated. Then each constant dollar payment is discounted at 7 percent (technique is shown in Attachment A).

Section 2

Discounting

To perform a valid economic evaluation of a project, it is necessary that all cash flows be stated in time-equivalent amounts. "Discounting" is the term often given to the technique for adjusting cash flows to time equivalency by taking into account the time value of money. This section is provided as a brief introduction to discounting because it is a fundamental tool used in solving all of the capital investment problems addressed by this seminar.

The following topics are treated in brief below:

(1) Definition

(2) Purpose

(3) Approach

(4) Selecting a Discount Rate

(5) Formulas (Table 2-1)

(6) Application

(7) Discount Factors Based on a 7% Discount Rate (Table 2-2)

(8) Discount Factors Based on a 10% Discount Rate (Table 2-3)

(9) Where to Find UPW* Factors for Discounting Energy Costs or Savings

(10) Problem Illustrations

Definition

Discounting is a technique for converting cash flows that occur at different times to equivalent amounts at a common time.

Purpose

The costs and benefits associated with building projects are typically spread over time. The dollar estimates of costs and benefits must be adjusted to a common time basis before they can be combined to determine a measure of economic performance. Because of the earning potential of money over time, as indicated by interest, a dollar now is worth more than a dollar at some later time.

Approach

Discounting is performed by applying interest (discount) formulas, or corresponding discount factors calculated from the formulas, to the estimated costs and savings that result from a given investment. The application of the appropriate formula or factor to a cash amount will convert that cost or saving to its equivalent value at the selected base time.

Selecting a Discount Rate

A key element in the discount formulas is the discount rate, the rate of interest reflecting the invester's time value of money. If future cash flows are stated in constant dollars, the discount rate should be selected to reflect only the real earning power of money over time; i.e., the time value of money remaining after inflation is removed. This is the approach recommended for Federal project evaluation. If future cash flows are estimated to include inflation, the discount rate can be selected to also include inflation, and the discounting technique can be used to adjust both for the effects of price inflation and for the real earning power of capital. This approach is often used for commercial project evaluation because it facilitates the treatment of tax effects. The relationship between a nominal discount rate, D, and a real discount rate, d, is as follows:

$$D = (1+d) \cdot (1+I) - 1 = d + I + dI$$

and $d = \frac{1+D}{1+I} - 1$, where I is the rate of general price inflation.

(See section on Escalation)

Application

The appropriate discount formula to use for adjusting a cash amount to an equivalent value at another time depends on the time distribution of the cash amount and the time basis selected by the analyst for the economic evaluation. For example, to find the equivalent value in the future of a single cash amount received today, the single compound amount formula (SCA) is used. To find the equivalent value in the future of a stream of uniform cash amounts over a period of years, the uniform compound amount formula (UCA) is used. To find the present value equivalent of a single amount to be received in the future, the single present worth formula (SPW) is used. To find the present value equivalent of a uniform series of future cash amounts, the uniform present worth formula (UPW) is used. And, to find the present value equivalent of a series of future amounts escalating in amount each year, the modified uniform present worth formula (UPW*) can be used. To express a present value as an equivalent uniformly recurring annual value, the uniform capital recovery formula (UCR) is used. The dollar amounts will, of course, differ depending on the time base chosen, but present values, annual values, and future values, if time-equivalents, will lead to the same investment decision. It is most customary in economic evaluations, however, to convert all cash flows to either present values or annual values, and, in the Federal Energy Management Program, the use of present values is requested to facilitate comparisons among agencies and projects.

Table 2.1 Discounting Equations

Name	Schematic Illustration	Application	Algebraic Form[a,b]
Single Compound-Amount (SCA) Equation	P ——→ F?	To find F when P is known	$F = P \cdot [(1+d)^N]$
Single Present-Worth (SPW) Equation	P? ←—— F	To find P when F is known	$P = F \cdot \left[\frac{1}{(1+d)^N}\right]$
Uniform Sinking-Fund (USF) Equation	A? + A? ···+ A? ← F	To find A when F is known	$A = F \cdot \left[\frac{d}{(1+d)^N - 1}\right]$
Uniform Capital-Recovery (UCR) Equation	P → A? + A? ···+ A?	To find A when P is known	$A = P \cdot \left[\frac{d(1+d)^N}{(1+d)^N - 1}\right]$
Uniform Compound-Amount (UCA) Equation	A + A ···+ A → F?	To find F when A is known	$F = A \cdot \left[\frac{(1+d)^N - 1}{d}\right]$
Uniform Present-Worth (UPW) Equation	P? ← A + A ···+ A	To find P when A is known	$P = A \cdot \left[\frac{(1+d)^N - 1}{d(1+d)^N}\right]$
Modified Uniform Present-Worth (UPW*) Equation[c]	P? ← A_1 + A_2 ···+ A_n	To find P when known A_0 is escalating at rate e	$P = A_0 \cdot \left(\frac{1+e}{d-e}\right) \cdot \left[1 - \left(\frac{1+e}{1+d}\right)^N\right]$

where:

- P = present sum of money,
- F = future sum of money equivalent to P at the end of N periods of time at d interest or discount rate,
- A = end-of-period payment (or receipt) in a uniform series of payments (or receipts) over N periods at d interest or discount rate,
- A_0 = initial value of a periodic payment (receipt) evaluated at the beginning of the study period,
- A_t = $A_0 \cdot (1+e)^t$, where $t = 1, \ldots, N$,
- N = number of interest or discount periods,
- d = interest or discount rate, and
- e = price escalation rate per period.

[a] Note that the USF, UCR, UCA, and UPW equations yield undefined answers when d = 0. The correct algebraic forms for this special case would be as follows: USF formula, A=F/N; UCR formula, A=P/N; UCA formula, F=A · N; and UPW formula, P=A · N. The UPW* equation also yields an undefined answer when e=d. In this case, $P = A_0 \cdot N$.

[b] The terms by which the known values are multiplied in these equations are the formulas for the factors found in discount factor tables. Using acronyms to represent the factor formulas, the discounting equations can also be written as F = P · SCA, P = F · SPW, A = F · USF, A = P · UCR, F=A · UCA, P=A · UPW, and $P = A_0 \cdot$ UPW*.

[c] To find P when A_0 escalates at a different rate over each of K escalation periods,

$$P = A_0 \sum_{j=1}^{n_1} \left(\frac{1+e_1}{1+d}\right)^j + \left(\frac{1+e_1}{1+d}\right)^{n_1} \sum_{j=1}^{n_2} \left(\frac{1+e_2}{1+d}\right)^j + \cdots$$

$$+ \left(\frac{1+e_1}{1+d}\right)^{n_1} \left(\frac{1+e_2}{1+d}\right)^{n_2} \cdots \left(\frac{1+e_{K-1}}{1+d}\right)^{n_{K-1}} \sum_{j=1}^{n_K} \left(\frac{1+e_K}{1+d}\right)^j ,$$

where n_i = the number of interest or discounting periods over which a given escalation rate, e_i, is assumed to hold

$$\left(N = \sum_{i=1}^{K} (n_i)\right), \text{ and } \sum_{j=1}^{n_i} \left(\frac{1+e_i}{1+d}\right)^j = \left(\frac{1+e_i}{d-e_i}\right) \left[1 - \left(\frac{1+e_i}{1+d}\right)^{n_i}\right]$$

Source: NBS Handbook 135.

Table 2-2 Discount Factors Based on 7% Discount Rate

	Single Compound Amount Factor SCA	Single Present Value Factor SPW	Uniform Capital Recovery Factor UCR	Uniform Present Value Factor UPW	Uniform Sinking Fund Factor USF	Uniform Compound Amount Factor UCA
Given / To Find	P / F	F / P	P / A	A / P	F / A	A / F
Period N						
1	1.070	.9346	1.070	.9346	1.0000	1.000
2	1.145	.8734	.5530	1.808	.4831	2.070
3	1.225	.8163	.3811	2.624	.3110	3.215
4	1.311	.7629	.2952	3.387	.2252	4.440
5	1.403	.7130	.2439	4.100	.1739	5.751
6	1.500	.6663	.2098	4.766	.1398	7.153
7	1.606	.6227	.1855	5.389	.1155	8.654
8	1.718	.5820	.1675	5.971	.0975	10.26
9	1.838	.5439	.1535	6.515	.0835	11.98
10	1.967	.5083	.1424	7.023	.0724	13.82
11	2.105	.4751	.1334	7.499	.0634	15.78
12	2.252	.4440	.1259	7.943	.0559	17.89
13	2.410	.4150	.1196	8.358	.0496	20.14
14	2.578	.3878	.1143	8.745	.0443	22.55
15	2.759	.3624	.1098	9.108	.0398	25.13
16	2.952	.3387	.1058	9.447	.0358	27.89
17	3.159	.3166	.1024	9.763	.0324	30.84
18	3.380	.2959	.0994	10.06	.0294	33.99
19	3.616	.2765	.0967	10.33	.0267	37.38
20	3.870	.2584	.0944	10.59	.0244	40.99
21	4.141	.2415	.0923	10.83	.0223	44.86
22	4.430	.2257	.0904	11.06	.0204	49.00
23	4.740	.2109	.0887	11.27	.0187	53.44
24	5.072	.1971	.0872	11.47	.0172	58.18
25	5.427	.1842	.0858	11.65	.0158	63.25
26	5.807	.1722	.0846	11.83	.0146	68.68
27	6.[illegible]14	.1603	.0834	11.99	.0134	74.48
28	6.649	.1504	.0823	12.14	.0124	80.70
29	7.114	.14056	.0814	12.28	.0114	87.35
30	7.612	.1314	.0805	12.41	.0106	94.46
31	8.145	.1227	.0798	12.53	.0098	102.0
32	8.715	.1147	.0791	12.65	.0091	110.2
33	9.325	.1072	.0784	12.75	.0084	118.9
34	9.978	.1002	.0778	12.85	.0078	128.3
35	10.68	.0937	.0772	12.95	.0072	138.2
36	11.42	.0875	.0767	13.03	.0067	148.9
37	12.22	.0818	.0762	13.12	.0062	160.3
38	13.08	.0764	.0758	13.19	.0058	172.5
39	13.99	.0715	.0754	13.26	.0054	185.6
40	14.97	.0668	.0950	13.33	.0050	199.6

All formulae assume end-of-period payments.

P = a present sum of money; F = a future sum of money, equivalent to P at the end of N periods of time at discount rate of d; A = an end of period payment (or receipts) in a uniform series of payments (or receipts) over N periods at d interest rates.

Table 2-3 Discount Factors Based on 10% Discount Rate

	Single Compound Amount Factor SCA	Single Present Value Factor SPW	Uniform Capital Recovery Factor UCR	Uniform Present Value Factor UPW	Uniform Sinking Fund Factor USF	Uniform Compound Amount Factor UCA
Given	P	F	P	A	F	A
To Find	F	P	A	P	A	F
Period N						
1	1.100	.9091	1.100	.9091	1.000	1.000
2	1.210	.8264	.5762	1.736	.4762	2.100
3	1.331	.7513	.4021	2.487	.3021	3.310
4	1.464	.6820	.3155	3.170	.2155	4.641
5	1.611	.6209	.2638	3.791	.1638	6.105
6	1.772	.5645	.2296	4.355	.1296	7.716
7	1.949	.5132	.2054	4.868	.1054	9.487
8	2.144	.4665	.1874	5.335	.0874	11.44
9	2.358	.4241	.1736	5.759	.0736	13.58
10	2.594	.3855	.1627	6.145	.0627	15.94
11	2.853	.3505	.1540	6.495	.0540	18.53
12	3.138	.3186	.1468	6.814	.0468	21.38
13	3.452	.2897	.1408	7.103	.0408	24.52
14	3.798	.2633	.1357	7.367	.0357	27.98
15	4.177	.2394	.1315	7.606	.0315	31.77
16	4.595	.2176	.1278	7.824	.0278	35.95
17	5.054	.1978	.1247	8.022	.0247	40.54
18	5.560	.1799	.1219	8.201	.0219	45.60
19	6.116	.1635	.1195	8.365	.0195	51.16
20	6.728	.1486	.1175	8.514	.0175	57.28
21	7.400	.1351	.1156	8.650	.0156	64.00
22	8.140	.1228	.1140	8.772	.0140	71.40
23	8.954	.1117	.1126	8.883	.0126	79.54
24	9.850	.1015	.1113	8.984	.0113	88.50
25	10.83	.0923	.1102	9.077	.0102	98.35
26	11.92	.0839	.1092	9.161	.0092	109.2
27	13.11	.0763	.1083	9.237	.0083	121.1
28	14.42	.0693	.1075	9.307	.0074	134.2
29	15.86	.0630	.1067	9.370	.0067	148.6
30	17.45	.0573	.1016	8.427	.0061	164.5
31	19.19	.0521	.1055	9.479	.0055	181.9
32	21.11	.0474	.1050	9.526	.0050	201.1
33	23.23	.0431	.1045	9.569	.0044	222.3
34	25.55	.0391	.1041	9.609	.0001	245.5
35	28.10	.0356	.1037	9.644	.0037	271.0
36	30.91	.0323	.1033	9.676	.0033	299.1
37	34.00	.0294	.1030	9.706	.0030	330.0
38	37.40	.0267	.1027	9.733	.0027	364.0
39	41.14	.0243	.1025	9.757	.0025	401.4
40	45.26	.0221	.1023	9.779	.0023	442.6

* All formulae assume end-of-period payments.

P = a present sum of money; F = a future sum of money, equivalent to P at the end of N periods of time at discount rate of d; A = an end of period payment (or receipts) in a uniform series of payments (or receipts) over N periods at d interest rates.

Where to Find UPW* Factors for Discounting Energy Costs or Savings

Modified Uniform Present Worth Factors (UPW*), based on a 7 percent discount rate for evaluating Federal energy projects, can be found in Appendix B of NBS Handbook 135, pp 118-128. These factors are given for each of 10 Department of Energy (DoE) regions, for different types of energy, and for residential, commercial, and industrial use. (As explained in the Handbook on pp. 116-117, these factors are subject to periodic revision. To obtain the most recent factors, contact the Federal Programs Office of the U.S. Department of Energy.)

Problem Illustrations

1. Find the present value (P) of a future amount of $5,000 in 10 years (N), assuming the discount rate (d) to be 10%.

   (a) Using the Single Present Worth (SPW) Discount Formula (from Workbook Table 2-1):

$$P = F \frac{1}{(1+d)^N}$$

$$= \$5,000 \cdot \frac{1}{(1 + .10)^{10}}$$

$$= (\$5,000) \cdot (0.3855)$$

$$= \$1,928$$

   (b) Using the SPW Discount Factor for d = 10% and N = 10 (from Workbook Table 2-3):

$$P = F \cdot SPW_{10yr,\ 10\%}$$

$$= (\$5,000) \cdot (0.3855)$$

$$= \$1,928$$

2. Find the present value (P) of a uniform series of annually recurring future amounts (A) of $2,000 per year over the next 10 years (N), assuming the discount rate (d) to be 7%.

   (a) Using the Uniform Present Worth (UPW) Discount Formula (from Workbook Table 2-1):

$$P = A \cdot \frac{(1+d)^N - 1}{d(1+d)^N}$$

$$= \$2,000 \cdot \frac{(1 + .07)^{10} - 1}{.07(1 + .07)^{10}}$$

$$= \$2,000 \cdot \frac{0.9672}{0.1377}$$

$= (\$2,000) \cdot (7.024)$

$= \$14,048$

(b) Using the UPW Discount Factor for d =7% and N=10 (from Workbook Table 2-2):

$P = A \cdot UPW_{10yr,\ 7\%}$

$= (\$2,000) \cdot (7.023)$

$= \$14,046$ (Note small difference due to rounding)

3. Find the future value (F) in 15 years (N) of a present amount (P) of $1,000, assuming a discount rate (d) of 10%.

(a) Using the Single Compound Amount (SCA) Formula (from Workbook Table 2-1):

$F = P \cdot (1+d)^N$

$= \$1,000 \cdot (1 + .10)^{15}$

$= (\$1,000) \cdot (4.177)$

$= \$4,177$

(b) Using the SCA Factor for d = 10% and N = 15 (from Workbook Table 2-3):

$F = P \cdot SCA_{15yr,\ 10\%}$

$= (\$1,000) \cdot (4.177)$

$= \$4,177$

4. Find the Future Value (F) in 15 years (N) of a uniform series of annually recurring amounts (A) of $1,000, assuming a discount rate (d) of 10%.

(a) Using the Uniform Compound Amount (UCA) Formula (from Workbook Table 2-1):

$$F = A \frac{(1+d)^N - 1}{d}$$

$$= \$1{,}000 \cdot \frac{(1 + .10)^{15} - 1}{.10}$$

$$= (\$1{,}000) \cdot (31.77)$$

$$= \$31{,}770$$

(b) Using the UCA Factor for d = 10% and N = 15 (from Workbook Table 2-3):

$$F = A \cdot UCA_{15yr,\ 10\%}$$

$$= (\$1{,}000) \cdot (31.77)$$

$$= \$31{,}770$$

5. Amortize in uniform annual payments (A) over 20 years (N) a present amount (P) of $100,000, assuming a discount rate (d) of 10%.

(a) Using the Uniform Capital Recovery (UCR) Discount Formula (from Workbook Table 2-1):

$$A = P \frac{(1+d)^N}{(1+d)^N - 1}$$

$$= \$100{,}000 \cdot \frac{.10\ (1 + .10)^{20}}{(1 + .10)^{20} - 1}$$

$$= (\$100{,}000) \cdot (0.1175)$$

$$= \$11{,}750$$

(b) Using the UCR Discount Factor for d = 10% and N = 20 (from Workbook Table 2-3):

$A = P \cdot UCR_{20yr,\ 10\%}$

$= (\$100{,}000) \cdot (0.1175)$

$= \$11{,}750$

6. Find the uniform amount that must be cumulated annually (A) in order to have a future amount (F) of $30,000 in 8 years (N), assuming a discount rate (d) of 7%.

   (a) Using the Uniform Sinking Fund (USF) Discount Formula (from Workbook Table 2-1):

$$A = F \cdot \frac{d}{(1+d)^N - 1}$$

$$= \$30{,}000 \cdot \frac{.07}{(1 + .07)^8 - 1}$$

$$= (\$30{,}000) \cdot (0.0975)$$

$$= \$2{,}925$$

   (b) Using the USF Discount Factor for d = 7% and N = 8 (from Workbook Table 2-2):

$A = F \cdot USF_{8yr,\ 7\%}$

$= (\$30{,}000) \cdot (0.0975)$

$= \$2{,}925$

7. Find the present value (P) of a non-uniform annually recurring amount ($\overline{A}$) that is valued at $5,000 at the beginning of the study period ($\overline{A}_0$), and escalates thereafter at 5% per annum (e) over 12 years (N), assuming a discount rate (d) of 12%.

   (a) Using the Uniform Present Worth Modified (UPW*) Discount Formula (from Workbook Table 2-1):

$$P = \overline{A}_o \cdot \frac{(1+e)}{(d-e)} \cdot \left[1-\left(\frac{1+e}{1+d}\right)^N\right]$$

$$= \$5,000 \cdot \frac{(1 + .05)}{(.12 - .05)} \cdot \left[1-\left(\frac{1 + .05}{1 + .12}\right)^{12}\right]$$

$$= \$5,000 \cdot [(15) \cdot (0.5390)]$$

$$= (\$5,000) \cdot (8.085)$$

$$= \$40,425$$

(b) Using the UPW* Discount Factor for d = 12% 5%, and N = 12 (from Handbook 135, Table B-14, p. 131):

$$P = \overline{A}_o \cdot UPW^*_{12yr,\ 12\%,\ 5\%}$$

$$= (\$5,000) \cdot (8.086)$$

$$= \$40,430$$ (Note small discrepancy due to rounding)

8. Find the present value (P) of the estimated cost of natural gas to heat a Federal office building in Minnesota over 10 years (N), assuming that the annual cost is initially valued at $10,000 ($\overline{A}_o$), and using the Federal discount rate of 7% for energy projects and the appropriate projected energy escalation rates.

(a) Using the Uniform Present Worth Modified (UPW*) Discount Formula for multiple escalation rates (from Workbook Table 2-1, footnote a); and the escalation rates for DoE Region 5, for the Commercial Sector, and for natural gas, of 8.87% for the period 1981-1985, 1.76% for 1985-1990, and 3.10% for 1990 and beyond (from Handbook 135, Table C-5, p. 138):

$$P = \overline{A}_o \left[\sum_{j=1}^{n_1} [(1+e_1)/(1+d)]^j + [(1+e_1)/(1+d)]^{n_1} \cdot \sum_{j=1}^{n_2} [(1+e_2)/(1+d)]^j + [(1+e_1)/(1+d)]^{n_1} \cdot [(1+e_2)/(1+d)]^{n_2} \cdot \sum_{j=1}^{n_3} [(1+e_3)/(1+d)]^j \right]$$

$$= \$10{,}000 \left[\sum_{j=1}^{2} [(1+.0887)/(1+.07)]^j + [(1+.0887)/(1+.07)]^2 \cdot \sum_{j=1}^{5} [(1+.0176)/(1+.07)]^j + [(1+.0887)/(1+.07)]^2 \cdot [(1+.0176)/(1+.07)]^5 \cdot \sum_{j=1}^{3} [(1+.0310)/(1+.07)]^j \right]$$

$$= \$10{,}000 \left[(1+.0887)/(.07-.0887) \cdot \left[1- [(1+.0887)/(1+.07)]^2\right] + [(1+.0887)/(1+.07)]^2 \cdot [(1+.0176)/(.07-.0176)] \cdot \left[1- [(1+.0176)/(1+.07)]^5\right] + (1+.0887)/(1+.07)^2 \cdot (1+.0176)/(1+.07)^5 (1+.0310)/(.07-.0310) \cdot \left[1- [(1+.0310)/(1+.07)]^3\right] \right]$$

$$= \$10{,}000\ [(-58.22) \cdot (-0.0353) + (1.035) \cdot (19.42) \cdot (0.222) + (1.035) \cdot (0.7780) \cdot (26.44) \cdot (0.1054)]$$

$$= \$10{,}000\ [2.055 + 4.462 + 2.244]$$

$$= (\$10{,}000) \cdot (8.761)$$

$$= \$87{,}610^*$$

(b) Using the Federal UPW* Discount Factor for DoE Region 5, for the Commercial Sector, for natural gas, for 10 years (from Handbook 135, Table B-5, p. 122):

$$P = \overline{A}_o \cdot UPW^*_{10yr,\ 7\%,\ DoE\ 5}$$

$$= (\$10{,}000) \cdot (9.60)$$

$$= \$96{,}000^*$$

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* Note discrepancy in (a) and (b) answers. The difference reflects the fact that the (a) calculations use the escalation rates directly, based on mid-1983 as the beginning of the study period, while the (b) calculations use UPW* factor tables based on mid-1981 as the beginning of the study period.

Section 3

Escalation

This section has the following objectives: to review the procedure for escalating costs, to distinguish budgetary needs for escalation from the requirements of economic analysis, and to compare economic evaluations made (a) in constant dollars using real escalation and discount rates and (b) in current dollars using nominal escalation and discount rates.

It contains the following topics:

(1) Escalation Procedure

(2) Budgetary Versus Economic Analysis Requirements for Cost Estimates

(3) Concept of Differential Price Escalation

(4) Constant Dollar Versus Current Dollar Analyses

Escalation Procedure

An initial amount, C_0, can be escalated at rate e over N periods of time to a future amount, C_N, by applying the single compound amount formula based on rate e and period N, to the initial amount; i.e., $C_N = C_0 (1+e)^N$.

An initial amount, C_0, can be escalated over N periods of time at changing escalation rates, $e_1, e_2, \cdots e_n$, each of which holds for a designated interval of time, $P_1, P_2 \cdots P_n$ (which together sum to a total of N compounding periods) as follows:

$$C_N = C_0(1+e_1)^{P_1} (1+e_2)^{P_2} \ldots (1+e_n)^{P_n}.$$

Budgetary Versus Economic Analysis Requirements for Cost Estimates

Budget estimates project the actual number of dollars expected to be required to purchase a building system or component at the planned time of acquisition. That is, budget estimates are generally stated in "current", or "nominal," dollars including projected price inflation.

In contrast, it is imperative in an economic analysis that all dollars have the same unit of purchasing power. Hence, purely inflationary or deflationary effects must be eliminated from projected cash flows in an economic analysis.

Concept of Differential Price Escalation

OMB Circular A-94 instructs Federal Agencies to make all estimates of future costs and benefits in constant dollars, reflecting in the estimates only changes in relative prices "where there is a reasonable basis for estimating such changes". Estimates should not include any forecasted change in the general price level.

We can define the relative price change in terms of a "differential escalation rate", i.e., the expected percentage difference between the rate of increase assumed for a given item of cost (such as energy), and the general rate of inflation. Let us denote the total escalation rate, "E"; the differential escalation rate, "e"; and the general rate of price inflation, "I".

Cash flows that are projected to increase in amount at about the same rate as general price inflation (i.e., $E = I$) have no real or differential escalation (i.e., $e = 0$), and, therefore, will remain unchanged in constant dollars from the initial amount. Routine maintenance costs, for example, are often assumed to remain the same in constant dollars.

Cash flows that change at a rate different from the rate of general price inflation (i.e., $E \neq I$ and $e \neq 0$), change in constant dollars. In a Federal analysis, the projected real or differential escalation rate, e, can be used with the single compound amount formula to calculate future amounts in constant dollars.

The three figures below illustrate three cases of differential escalation. In each figure, time is measured on the x-axis and dollar costs on the y-axis. The solid line in each figure, projected from the y-axis, traces the actual rise in price over N years of an item which initially costs C_0. That is, the solid line, defined by the equation $C_E = C_0 (1 + E)^N$, depicts current dollar costs for a given E over N years. The dashed line in each figure traces the rise in cost over N years that would occur if the item increased in price at the rate of general price inflation, I. It is defined by the equation $C_I = C_0 (1 + I)^N$. The dashed-dot line traces the change in constant dollar cost over N years. It is defined by the equation $C_c = C_0 (1 + e)^N$.

Figure 1, where the dashed line and solid line are coincident, shows the case for which the rate of total change in the price of the item, E, is just equal to the rate of change in the general price level, I (i.e., the differential escalation rate, e, is zero). In this case, the future current dollar cost

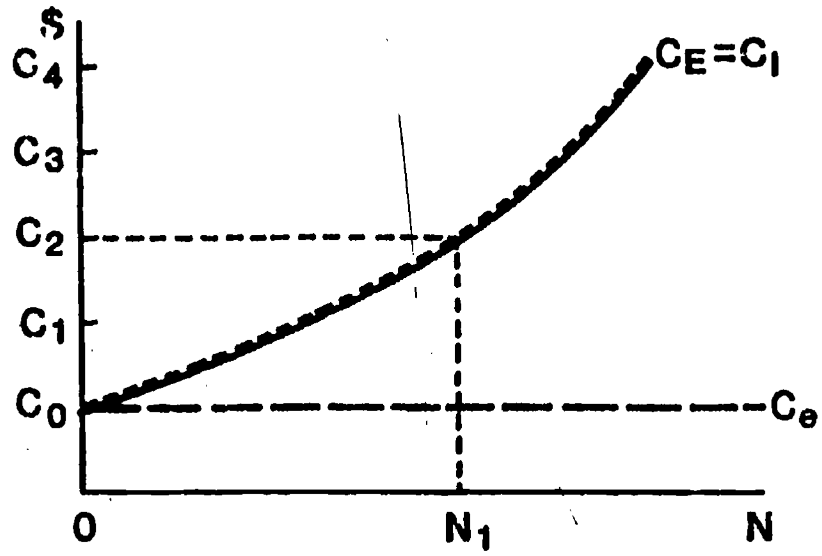

Fig. 3-1 Change in Dollar Values Over Time as a Function of Price Escalation: E = I and e = 0.

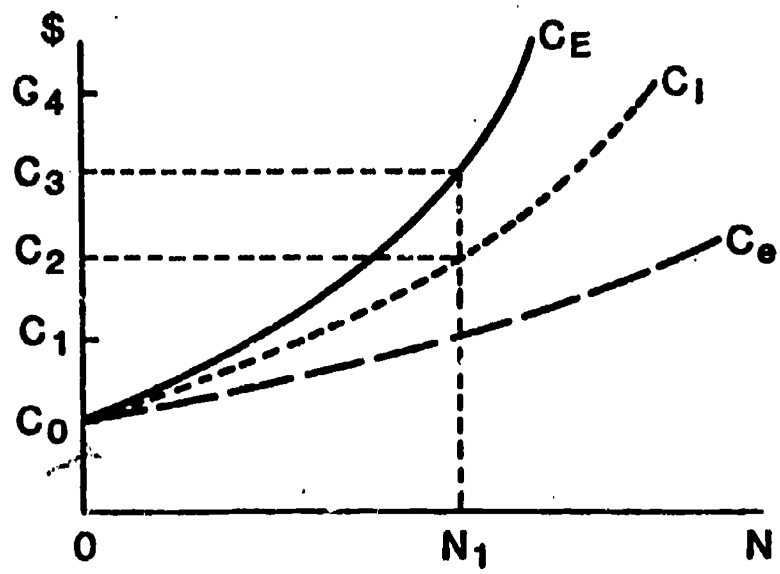

Fig. 3-2 Change in Dollar Values Over Time as a Function of Price Escalation: E > I and e > 0.

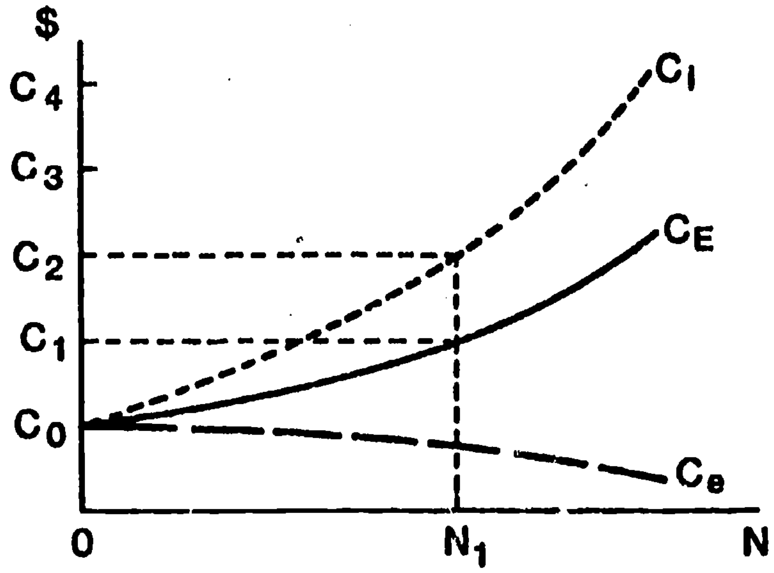

Fig. 3-3 Change in Dollar Values Over Time as a Function of Price Escalation: E < I and e < 0.

in N_1 years is C_2, i.e., $C_0 (1 + E)^{N_1} = C_2$. But in <u>constant</u> dollars, the future cost, C_e, is still C_0, because $e = 0$ and the constant dollar cost, C_e, is equal to $C_0 (1 + e)^N$.

Figure 2 describes costs for the case where the rate, E, of total change in the price of the item exceeds the rate, I, of change in the general price level, such that the differential rate, e, is positive. In this case, the future current dollar cost in year N_1 is greater than C_2--it is C_3 in the example--and in constant dollars the future cost, C_e, is higher than C_0, because $E > I$ and $e > 0$.

Figure 3 shows dollar costs for the case where the rate, E, of total change in the price of the item is less than the rate, I, of change in the general price level, such that the differential rate, e, is negative. In this case, the future current dollar cost, C_E, in year N_1 is less than C_2--it is C_1 in the example--and in constant dollars the future cost, C_e, is below C_0 because $E < I$ and $e < 0$.

Constant Dollar Versus Current Dollar Analyses

When future costs and benefits are stated in constant dollars, incorporating only the relative price change and excluding inflation, it is appropriate to discount the future values to a common time basis using a real discount rate, denoted "d", which does not include inflation. The 7 percent discount rate specified for evaluating Federal energy conservation projects and the 10 percent discount rate specified for evaluating other kinds of Federal projects (not specifically exempted) are both real discount rates.

When future cash flows are estimated to include inflation, the discount rate should also include inflation; that is, a nominal discount rate, which can be denoted "D," should be used for discounting current dollar cash flows. Market interest rates are nominal rates. The weighted cost of capital (expressed as a percent), which is often used by corporations as a discount rate, is a nominal rate.

If correctly formulated, an analysis in constant dollars worked with a real discount rate will yield the same result as an analysis in current dollars worked with a nominal discount rate. While the constant dollar approach is recommended for Federal analyses, the current dollar approach is often preferred for the analysis of taxable investments because it can facilitate the analysis of tax effects.

To see the relationships between the two approaches, the following relationships should be noted:

a) $$E = (1 + e)(1 + I) - 1 = e + I + eI,$$

b) $$e = \frac{1 + E}{1 + I} - 1,$$

c) $$D = (1 + d)(1 + I) - 1 = d + I + dI, \text{ and}$$

d) $$d = \frac{1 + D}{1 + I} - 1 .$$

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where

E = the rate of total change in the price of a given item,

e = the differential rate of change in the price of the item,

I = the rate of general price inflation,

D = a nominal discount rate, and

d = a real discount rate.

By pairing E and D for escalation and discounting, purely inflationary effects cancel out of the analysis. By pairing e and d for escalation and discounting, purely inflationary effects are simply omitted from the analysis.

References:

Discussion of the Causes of Changing Monetary Values Over Time--See Handbook 135, pp. 7-8.

Federal Energy Price Escalation Rates--See Tables C-1 through C-11, Handbook 135, pp. 134-144.

UPW* Factors for Combined Escalation and Discounting--See Tables B-1 through B-11, Handbook 135, pp. 118-128.

UPW* Factors for Combined Escalation and Discounting Based on Various Discount Rates and Escalation Rates (Non-Specific to Federal Energy Costs)--See Tables B-12 through B-14, Handbook 135, pp. 129-131.

Year-By-Year Method of Calculating the Value of Energy Savings (when it is necessary to adjust for changes in the annual quantity or source of energy)--See Appendix G, Table G-2, and accompanying text, Handbook 135, pp. 219-223.

Section 4

Study Period

The purpose of this section is to provide guidelines for setting the length of the study period, the time over which project costs and benefits will be assessed. The discussion is organized into the following parts:

(1) Maximum Study Period

(2) Selecting a Study Period for Present Value Comparisons of Projects

(3) Selecting a Study Period for Savings-to-Investment Ratio (SIR) Comparisons of Projects

(4) Reconciling Project Life and Study Period

(5) Delays Between the Time of Project Evaluation and Project Initiation

Maximum Study Period

For evaluating Federal energy conservation projects, an upper limit of 25 years is set for the study period, reflecting uncertainty in projecting energy prices for longer periods of time.

Selecting a Study Period for Present Value Comparisons of Projects

For selecting among mutually exclusive project alternatives based on present value LCC or NS, the same study period should be used to evaluate the alternatives. The use of different study periods would result in different present values even if the alternatives were equal in cost effectiveness.

Reference: See Section 3.10, Handbook 135, pp. 33-34.

Selecting a Study Period for SIR Comparisons of Projects

The rankings of projects according to their SIR's will not be affected by having different study periods for different projects <u>if</u> there is no differential price escalation included in project cash flows. If differential price escalation <u>is</u> included, the comparative rankings of projects may be affected somewhat by the use of unequal study periods. In this case, the use of equal study periods will avoid any biasing of results. The life-cycle cost guidelines of the Federal Energy Management Program, however, do not require that all projects be evaluated for the same study period when ranking them according to their SIR's. This decision reflects the desire to simplify the evaluation procedure where possible. The simplification in this case is the avoidance of many repetitions of the calculations for short-lived projects.

Reconciling Project Life and Study Period

Replacement and salvage values are used to reconcile differences between study periods and project or component lives when these are unequal.

Delays Between the Time of Project Evaluation and Project Initiation

Economic analyses performed for the purpose of determining the cost effectiveness of a project generally do not give the same level of attention to the details of cash flows during the planning and construction phase as would a cost analysis aimed at <u>controlling</u> construction costs. Often the following two simplifying assumptions are made: (a) all construction costs occur at the outset of the study period, which is coincident with the time the analysis is performed, (b) operational costs accrue at the end of each year thereafter. In most cases, the inaccuracies introduced by these assumptions will be small and will not affect the decision.

In choosing among projects with substantially different time delays, however, it may be important to take into account those delays, since the relative cost effectiveness of the projects may be affected. For example, suppose the choice were between two mutually exclusive energy retrofit projects, each with a 10 year life, for a facility expected to be in service another 10 years. If one alternative could be implemented immediately, but the other would require a delay of 5 years, the timing of the projects would be relevant to the choice, since the effective life of one of the alternatives is reduced to 5 years and benefits during the delay interim are lost to that alternative.

In comparing the life-cycle costs of a project with a delay in implementation against the life-cycle costs of a base case condition (i.e., not having the project), a distinction should be made between those costs which can be avoided during the delay period if the project will eventually be undertaken, and those which cannot be avoided. Consider, for example, a proposed project which could be implemented three years from the present. If knowledge that the proposed project were forthcoming would allow the avoidance of certain costs during the interim three years that would otherwise be incurred under the base case, the cost avoidances should be attributed to the proposed project. This can be done by including these costs in the Base Case but not in the Proposed Project costs. Costs that cannot be avoided during the interim (i.e., those that are sunk) can either be included in both the evaluation of the Base Case and the Proposed Project or omitted from both, since they will in any case cancel out of the analyses.

Section 5

Project Selection

The term "project selection" is used here to cover the following types of project investment decisions, each of which is discussed below:

(1) Accepting or Rejecting a Given Project

(2) Designing and Sizing Individual Projects

(3) Ranking Projects for Funding Priority

(4) Determining Combinations of Interdependent Projects

(5) Jointly Designing/Sizing and Ranking Projects

Following the discussion of each of these decisions, a problem example is given with step-by-step solution. The problem solution illustrates how the following techniques of economic evaluation are used in project selection:

- Life-Cycle Costing (LCC)
- Net Benefits (NB) or Net Savings (NS)
- Benefit-to-Cost Ratio (BCR) or Savings-to-Investment Ratio (SIR)
- Payback — Simple (SPB) or Discounted (DPB)

References:

Definitions, Formulas, and Applications of Evaluation Techniques — see Section 2.3, Handbook 135, pp. 14-22.

Accepting or Rejecting a Given Project

A project is usually deemed cost effective if (a) its life-cycle costs are lower than other alternatives for achieving the same objective, one of which must be adopted; (b) it results in benefits or savings in excess of its costs; (c) it yields an internal rate of return higher than the minimum acceptable rate of return; (d) the ratio of overall net cash flow is positive after payback is achieved.

Cost-effective projects are "worth doing," other things being equal, but further analysis may be needed to determine if a given project should be selected over other project choices.

References:

Discussion--See Section 2.4.1, Handbook 135, p. 22.

Accept-Reject Problem Example: See Workbook Section 11, Problem Set A, "Programmable Time Clock Problem"

Designing and Sizing Individual Projects

Often the decision maker has choices of design, size, material, or other attributes of a given project. These are "mutually exclusive" alternatives in that choosing one means not choosing another. The economic objective is to choose the alternative which results in the greatest net benefits or net savings. If the alternatives are considered apart from possible budget constraints, the economically efficient choice will satisfy at least one of the following conditions: (a) project life-cycle costs are minimum; (b) project net benefits or net savings are maximum; or (c) the ratio of benefits or savings to costs for the last increment of investment is one; or (d) the yield on the last increment of investment approaches the minimum acceptable rate of return.

References:

Discussion--See Sections 2.4.2 and 2.4.3, Handbook 135, pp. 24-25.

Sizing Example: See at the end of this Section, "Pipe Insulation Retrofit Problem--A Case Example of Project Selection"

Ranking Projects for Funding Priority

When funds are limited and there are more cost-effective projects than can be funded, choices must be made among non-mutually exclusive projects, i.e., projects for which acceptance of one would not preclude the acceptance of others, aside from the funding constraint.

The economic objective is to select the combination of projects that will maximize net benefits or net savings for the available budget. This can often be done by ranking and selecting projects in descending order of their benefit-to-cost or savings-to-investment ratios, until the budget is exhausted. If the project ratios fall below one before the available budget is exhausted, then project acceptance should terminate with the last project whose ratio exceeds one. If, due to "lumpiness" in project size, higher ranked projects cost more than the available budget, while lower ranked projects are affordable within the budget, lower ranked projects (but with ratios greater than one) should be selected in descending order until the budget is exhausted.

References:

Discussion--See Section 2.4.4, Handbook 135, pp. 25-26.

Ranking Projects Example: See at the end of this Section, "Pipe Insulation Retrofit Problem--A Case Example of Project Selection," and Workbook Section 12, Problem Set B, "Water Conservation Problem"

Determining Combinations of Interdependent Projects

In evaluating candidate projects for a particular building or facility, the problem of interdependency among projects may arise; that is, undertaking one project may affect the relative life-cycle costs and savings of remaining projects. For example, the value of adding an automatic environmental control system will differ depending on the level of insulation in the building envelope and vice versa. Undertaking one will tend to diminish the value of the other. An approach to this problem is to evaluate each of the candidate projects independently of one another, select first the one with the highest BCR or SIR value, and then adjust the BCR or SIR value of any remaining projects that are expected to be substantially altered by the first, higher priority, selection. The selection process would then be continued, with necessary adjustments to remaining projects being made as each project is chosen.

References: See Workbook Section 12, Problem Set B, "Team Problem--Planning an Energy Conservation Package"

Jointly Designing/Sizing and Ranking Projects

Where there are several, non-mutually exclusive projects with positive net benefits and there is an insufficient budget to fund all of them, the theoretically correct approach would be to size each project such that the incremental BCR or SIR would be equal for all projects and equal to the ratio available on the last increment of the next best investment (i.e., equal to the opportunity cost). Then projects would be selected on the basis of descending BCR's or SIR's computed on the total project costs and benefits (savings) until the budget is exhausted.

Due to the difficulty of simultaneously equating the incremental ratios on all projects, second-best approaches are often used. One is to size each project so that the incremental ratio is equal to one, and then select projects as before in descending order of BCR's or SIR's until the budget is exhausted. This may lead to inefficient, oversized projects when there are budget constraints. A second approach, and one that is generally preferred to the first one, is to set up the sizing decisions when possible in the same context as the ranking decisions under a budget constraint, thereby constructing the problem in such a manner that the sizing of given projects and ranking of a set of projects will occur simultaneously.

<u>References:</u>

Problem Example: See at the end of this Section, "Pipe Insulation Retrofit Problem--A Case Example of Project Selection"

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Pipe Insulation Retrofit Problem -- A Case Example of Project Selection

[Note: This is a hypothetical example for use only to illustrate the evaluation technique.]

This case demonstrates (a) the discounting of costs and savings; (b) the use of the evaluation techniques of life-cycle cost (LCC), savings-to-investment ratio (SIR), and discounted payback (DPB) to determine if a project is cost effective; (c) the use of net savings (NS) and incremental SIR (ΔSIR) to determine efficient project size if there is no budget constraint; and (d) the use of the SIR and ΔSIR to rank the project and its size increments relative to other projects competing for limited funds.

Problem Statement

Approximately 100 ft of hot water pipes running through the basements of each of 10 buildings of a Federal laboratory facility in Massachusetts have been found to be uninsulated. Data and assumptions are as follows:[a]

Quantity of Uninsulated Pipe: 100 ft/Bldg x 10 Bldgs = 1,000 ft
Required Water Temperature: 180°
Pipe Size: 1 1/2" Diameter
Operation: 4 hr/day x 260 days/yr = 1,040 hrs/yr
Type of Energy: Distillate Oil
Agency Base-Year Price of Distillate: $9.00/10^6 Btu
Plant Efficiency: .55
Remaining Building Life: Indefinite
Insulation Life: Indefinite
Available Insulation Choices: 1" or 2" of Fibrous Material

[a]For the purpose of demonstrating the basic procedures, this sample problem is kept simple. In actual practice, there would likely be other considerations for energy conservation than those included here, such as the possibility of reducing the water temperature.

Step 1. Calculate the quantity of annual energy savings (AES) for the alternative sizes of insulation

o Formulate Estimating Relationship:

$$AES\ (10^6 Btu) = \frac{\Delta HLR/hr/ft \cdot hrs/yr \cdot ft}{eff \cdot 10^6},$$

where AES = annual quantity of energy savings,

ΔHLR = decrease in Btu heating load requirements, and

eff = plant efficiency.

(Note: The numerator is divided by 10^6 in order to state AES in terms of millions of Btu.)

o Refer to Figure 5-1 (or use other appropriate approaches) to estimate the value of ΔHLR/hr/ft with and without the insulation.

o Refer to Problem Assumptions for the number of hours, linear feet of pipe, and plant efficiency.

o Calculate AES:

$$AES_{1"} = \frac{(150 - 20) Btu/hr/ft \cdot 1{,}040\ hrs/yr \cdot 1{,}000\ ft}{0.55 \cdot 10^6}$$

$$= 245.8 \times 10^6 Btu$$

$$AES_{2"} = \frac{(150 - 12.5) Btu/hr/ft \cdot 1{,}040\ hrs \cdot 1{,}000\ ft}{0.55 \cdot 10^6}$$

$$= 260.0 \times 10^6 Btu$$

Step 2. Calculate the present value of energy cost savings (PV_{ES}) over the life cycle (study period) for the alternative sizes

o Formulate the estimating relationships:

$$PV_{ES} = AES \cdot P/10^6 Btu \cdot UPW^*$$

where PV_{ES} = present value dollar energy savings over the study period,

AES = annual quantity of energy savings,

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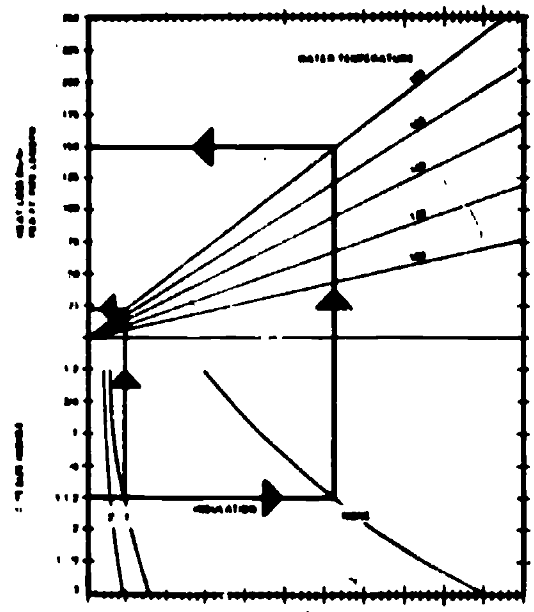
Figure 5-1

LCC PROBLEM SOLUTION — ESTIMATION OF ENERGY SAVINGS

Determine Heat Loss Rates With & Without Insulation:



- **Uninsulated Pipe: 150 BTU/hr/ft**
- **1" Insulated Pipe: 20 BTU/hr/ft**
- **2" Insulated Pipe: 12.5 BTU/hr/ft**

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$P/10^6Btu$ = initial price per 10^6Btu of energy, and

UPW* = modified uniform present worth discount factor.

- Designate the length of the study period.
- Refer to Problem Assumptions for initial price of energy.
- Refer to Problem Assumptions for the DoE Region in which the laboratory facility is located, the nature of the building (residential, commercial, industrial), and the type of energy, and find the corresponding UPW* for the appropriate study period from Appendix B of Handbook 135. In this case the UPW* = 17.77 (from Table B-1, Handbook 135, p. 118).
- Calculate PV_{ES}:

For 1" of Insulation:

$$PV_{ES_{1"}} = 245.8 \times 10^6 Btu \cdot \$9.00/10^6 Btu \cdot 17.77$$

$$= \$39,311.$$

For 2" of Insulation:

$$PV_{ES_{2"}} = 260.0 \times 10^6 Btu \cdot \$9.00/10^6 Btu \cdot 17.77$$

$$= \$41,582.$$

Step 3. Calculate project investment costs for the alternative sizes of insulation

- Formulate the Estimating Relationship:

I = P/ft x ft x (1 - FEMP Adj. Factor),

where I = project investment cost (in present value $),

P/ft = price per linear foot of insulation,

ft = linear feet required, and

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FEMP Adj. Factor = 10% reduction in investment costs as a rough measure of the social benefits of energy conservation not reflected in market prices. (Note: this was established as a temporary procedure which may be eliminated.)

o Refer to Table 5-1 (or use other appropriate approach) to estimate Project Investment Costs.

o Calculate Investment Costs:

$I_{1"} = \$2.50/ft \cdot 1{,}000\ ft \cdot 0.9$

$= \$2{,}250.$

$I_{2"} = \$4.55/ft \cdot 1{,}000\ ft \cdot 0.9$

$= \$4{,}095.$

Step 4. Calculate present value net savings for the alternative sizes of insulation

o Formulate the estimating relationship:

$$NS = PV_{ES} - I$$

where NS = net savings in present value dollars,

PV_{ES} = present value energy savings,

I = project investment cost.

o Calculate NS:

$NS_{1"} = \$39{,}311 - \$2{,}250$

$= \$37{,}061.$

$NS_{2"} = \$41{,}582 - \$4{,}095$

$= \$37{,}487.$

Table 5-1 Costs for Insulating Various Pipe Sizes

Pipe Size (Inches)	Installed Cost/Linear Foot of Pipe Insulation* 1 Inch Thickness (Fibrous Material) ($)	2 Inch Thickness (Fibrous Material) ($)
1/2	2.00	3.70
3/4	2.10	3.95
1	2.20	4.15
1 1/4	2.40	4.45
1 1/2	2.50	4.55
2	2.70	4.74
2 1/2	2.85	5.15
3	3.10	5.45
3 1/2	3.40	5.80
4	3.90	6.40
5	4.30	7.20
6	4.80	7.75
8	6.45	9.55
10	7.20	11.[illegible]5
12	8.30	12.25

Source: Mechanical and Electrical Cost Data 1979, R. S. Means Co., Inc.

* These are average installed costs, including labor and materials, for pipe located in accessible areas. Inaccessibility would cause increases in costs.

Note: There is a small discrepancy in this example between the year's dollars in which energy savings and investment costs are expressed. That is, the UPW* factors used to find the present value of energy savings are based on a mid-1981 starting point, whereas the above investment costs are in 1979 dollars. To provide a greater degree of accuracy, investment cost data for 1981 could be used, or, if they were not available, the 1979 prices could be adjusted to a 1981 basis by applying to them a ratio comprised of a 1981 price index divided by a 1979 price index for the appropriate category of building materials.

Step 5. Answer the question, "Is it cost effective to insulate the laboratory hot water pipes?"

Answer: Positive net savings indicate that the investment <u>is</u> cost effective.

Step 6. Verification of Project Cost Effectiveness by Other Evaluation Techniques. [Note: This step is unnecessary in so much as the NS technique is reliable for determining cost effectiveness; it is included only to illustrate the use of other techniques.]

<u>Life-Cycle Costing (LCC) Evaluation</u>

Approach: Calculate the total present value of energy costs plus other costs over the study period for the base case (i.e., without the retrofit project) and for the proposed retrofit project in its alternative sizes, and see if the total is lower with the project.

- Calculate present value life-cycle costs for the base case (LCC_{BC}):

$$LCC_{BC} = \frac{(150 \text{ Btu/hr/ft} \quad 1{,}040 \text{ hrs} \cdot 1{,}000 \text{ ft})}{0.55 \cdot 10^6} \cdot \$9.00/10^6\text{Btu} \cdot 17.77$$

$= \$45,362.$

- Calculate present value life-cycle costs with the retrofit project for each size alternative (LCC_R):

$$LCC_{R_{1"}} = \frac{(20 \text{ Btu/hr/ft} \cdot 1{,}040 \text{ hr} \cdot 1{,}000 \text{ ft})}{0.55 \cdot 10^6} \cdot \$9.00/10^6\text{Btu} \cdot 17.77 + \$2{,}250$$

$= \$8,298.$

$$LCC_{R_{2"}} = \frac{(12.5 \text{ Btu/hr/ft} \cdot 1{,}040 \text{ hr} \cdot 1{,}000 \text{ ft})}{0.55 \cdot 10^6} \cdot \$9.00/10^6\text{Btu} \cdot 17.77 + \$4{,}095$$

$= \$7,875.$

Conclusion: Life-cycle building costs are lower with the project in either size alternative than without it, indicating that the project in either size is cost effective.

Savings-to-Investment Ratio (SIR) Evaluation

Approach: Calculate the SIR for each project size alternative and see if it exceeds 1.

$$SIR_1 = \left[\frac{(150-20)\text{Btu/hr/ft} \cdot 1{,}040 \text{ hr} \cdot 1{,}000 \text{ ft}}{0.55 \cdot 10^6} \cdot \$9.00/10^6\text{Btu} \cdot 17.77\right] \div \$2{,}250$$

$$= 17.47$$

$$SIR_2 = \left[\frac{(150-12.5)\text{Btu/hr/ft} \cdot 1{,}040 \text{ hr} \cdot 1{,}000 \text{ ft}}{0.55 \cdot 10^6} \cdot \$9.00/10^6\text{Btu} \cdot 17.77\right] \div \$4{,}095$$

$$= 10.15$$

Conclusion: The SIR is greater than 1 for both size alternatives, indicating that either is cost effective.

Discounted Payback (DPB) Evaluation

Approach: Calculate the cumulative present value energy savings for each project size and determine in what year (Y) the cumulative discounted savings exceed the investment cost for that size alternative, i.e., for what Y is $PV_{ES}(Y) - I > 0$.

The cumulative net savings numbers shown in table 5-2 are calculated as follows:

$$PV_{ES_1}(Y=1)-I = \left[\frac{(150-20)\text{Btu/hr/ft} \cdot 1{,}040 \cdot 1{,}000 \text{ ft}}{0.55 \cdot 10^6} \cdot \$9.00/10^6\text{Btu} \cdot \underset{\text{UPW* for N=1}}{0.96}\right]$$

$$-\$2{,}250 = -\$126.$$

$$PV_{ES_{1"}}(Y=2)-I=\left[\frac{(150-20)\text{Btu/hr/ft} \cdot 1{,}040 \cdot 1{,}000 \text{ ft}}{0.55 \cdot 10^6} \cdot \$9.00/10^6\text{Btu} \cdot \underset{\text{N=2}}{\overset{\text{UPW* for}}{1.88}}\right]$$

$$-\$2{,}250 = \$1{,}909.$$

$$PV_{ES_{2"}}(Y=1)-I=\left[\frac{(150-12.5)\text{Btu/hr/ft} \cdot 1{,}040 \text{ hr} \cdot 1{,}000 \text{ ft}}{0.55 \cdot 10^6} \cdot \$9.00/10^6\text{Btu} \cdot 0.96\right]$$

$$-\$4{,}095 = -\$1{,}849.$$

$$PV_{ES_{2"}}(Y=2)-I=\left[\frac{(150-12.5)\text{Btu/hr/ft} \cdot 1{,}040 \text{ hr} \cdot 1{,}000 \text{ ft}}{0.55 \cdot 10^6} \cdot \$9.00/10^6\text{Btu} \cdot 1.88\right]$$

$$-\$4{,}095 = \$304.$$

Table 5-2. Discounted Payback Solution

Y	Cumulative Present Value Energy Savings		Cumulative Net Savings	
	1" Insulation	2" Insulation	1" Insulation	2" Insulation
0	0	0	-$2,250	-$4,095
1	2,124	2,246	-126	-1,849
2	4,159	4,399	1,909	304

Conclusion: For both size alternatives, payback occurs in the second year--long before project life and energy savings are expected to end. Since there are no anticipated project costs after initial installation, the project in either size is cost effective.

Step 7. Answer the question, "Which Project Size is Most Cost Effective?"

Answer: 2" insulation results in greater net savings than 1" and, therefore, 2" is more cost effective if there is no budget limitation.

Step 8. Verification of Most Cost-Effective Project Size by Other Evalution Techniques. [Again note that this step is unnecessary and is included merely to illustrate the use of other techniques.]

Life-Cycle Costing (LCC) Evaluation

Approach: Compare LCC's of size alternatives to see which is less:

Size Alternative	LCC ($)
1"	8,298
2"	7,875

Conclusion: LCC is lower with 2" of insulation than with 1", indicating that 2" is more cost effective if there is no budget limitation.

Incremental SIR (ΔSIR) Evaluation

Approach: Determine if the ΔSIR is greater than 1. Note that the ΔSIR is the ratio of savings to investment for the last increment of investment, in this case the extra investment required to increase insulation thickness from 1" to 2"; i.e., $4,095 - $2,250 = $1,845. The incremental dollar savings is based on the reduction in the hourly heat loss rate from 20 Btu/hr/ft with 1" of insulation to 12.5 Btu/hr/ft with 2" of insulation.

$$\Delta SIR_{1'' \rightarrow 2''} = \frac{(20-12.5)\text{Btu/hr/ft} \cdot 1{,}040 \cdot 1{,}000 \text{ ft}}{0.55 \cdot 10^6} \cdot \$9.00/10^6\text{Btu} \cdot 17.77$$

$$\div (\$4{,}095 - \$2{,}250)$$

$$= 1.23.$$

Conclusion: The ΔSIR is greater than 1, indicating that the additional expense of the added insulation thickness is more than offset by the extra energy savings, such that the 2" size is more cost effective than 1" if there is no budget limitation.

[Cautionary Note: The SIR computed on total investment and total savings data does not provide a reliable technique for sizing projects. The SIR for the 1" thickness, for example, is 17.47, substantially higher than the SIR for the 2" thickness of 10.15, yet the incremental investment <u>is</u> cost effective. (The discounted payback technique has the same type of shortcoming for sizing projects as the SIR.)]

Step 9. Answer the question, "What Priority Should This Project Receive Relative to Other Projects if the Budget is Insufficient to Allow Acceptance of All Available Cost-Effective Projects?"

Approach: The economic objective in setting priorities is to choose the projects that will result in the greatest net benefits from the available budget. Assigning project priorities based on the descending order of project SIR's provides a workable approach for achieving (or closely approximating) this objective.

When there is a budget constraint, project sizing can often be accomplished in conjunction with project ranking by breaking projects into their size increments, computing SIR's on those increments, and ranking the increments relative to other potential projects. Assume, for example, that the illustrative pipe retrofit project using a 1" thickness of insulation is designated Project A, and the project increment required to increase thickness from 1" to 2" is designated Project B. Projects A and B can then be assigned priority relative to other projects C, D, E, F, and G--all of which are competing for the limited funds available--according to their SIR's, as shown in table 5-3.

Table 5-3. Joint Sizing and Ranking of Projects

Potential Projects	SIR	Project Ranking for Priority
A (0→1" of Insulation)	17.47	2
B (1→2" of Insulation)	1.23	5
C	1.15	6
D	15.50	3
E	25.00	1
F	12.52	4
G	0.75	not acceptable

Since it is cost effective to choose all projects with SIR's greater than 1, 2" of insulation will be selected over 1" if sufficient funds remain after Projects E, A (1" of insulation), D, and F are funded.

In practice, the sizing decision and the project priority decision are often treated separately, rather than jointly as shown above. A project may first be sized as though there were no budget constraint (i.e., 2" thickness of insulation), and then assigned priority relative to other projects based on the SIR computed on the size selected. Using this approach in the above example, Project A (1" of insulation; SIR = 17.47) and Project B (the increment from 1" to 2" of insulation; SIR = 1.23) would not be separately identified in the ranking. Rather a single project entry (designated $\overline{A}$) would be made, based on total values for 2" of insulation (SIR= 10.15), as shown in table 5-4.

Table 5-4. Ranking of Projects of Predetermined Size

Potential Projects	SIR	Project Ranking for Priority
$\overline{A}$ (2" of Insulation)	10.15	4
C	1.15	5
D	15.50	2
E	25.00	1
F	12.52	3
G	0.75	not acceptable

This latter approach results in a different relative priority of the projects than the former approach. A disadvantage of this approach is that if funds are very limited, the project may not be done at all, even though its first increment (1") is estimated to be more cost-effective than projects D and F which now receive higher priorities. An advantage of the approach is that the projects which are selected will be sized so as to avoid the loss of potential net benefits. For example, if 1" thick pipe insulation is installed, there will not likely be another opportunity to capture the additional net benefits that would have resulted from the additional thickness of 2". The relative merits of the approaches depend to a large extent on (a) the severity and duration of funding shortages and (b) the costs of later additional retrofit.

Section 6

Sensitivity Analysis

Some of the costs and most of the benefits of capital investment projects occur in the future, necessitating forecasting of their values. Since forecasted data are usually uncertain, the findings of the economic evaluation will also tend to be uncertain. In addition, there are often unknown elements even in the very short run which may cause estimated values to deviate from actual values. Sensitivity analysis is one approach for taking into account uncertainty in economic evaluations. This section briefly treats the technique in three parts:

(1) Approach

(2) Applications

(3) Examples

Approach

Sensitivity analysis is performed by simply repeating a project evaluation, with each repetition based on a different value of the factor in question.

Applications

Sensitivity analysis is used in three main ways: (1) to identify critical parameters, (2) to address "what if" questions, and (3) to establish upper and lower bounds for the estimated outcome. Sensitivity analysis is used to identify the factors that are critical to a project's success by changing in turn or in combination the values of factors in the analysis by given percentages and observing the corresponding percentage changes in the measure of economic performance.

Sensitivity analysis is used to address "what if" questions (such as how worthwhile will the project be if a certain component lasts only half as long as the manufacturer claims) by finding the outcome under the hypothesized condition. The technique is used to set upper and lower bounds of estimated outcome by repeating the analysis for the worst case and the best case.

Examples

Figure 6-1 illustrates a project choice that is sensitive to the length of time over which the project will be required. For a study period of less than about 10 years, B has the lower life-cycle cost, but for a study period greater than 10 years, A has the lower life-cycle cost.

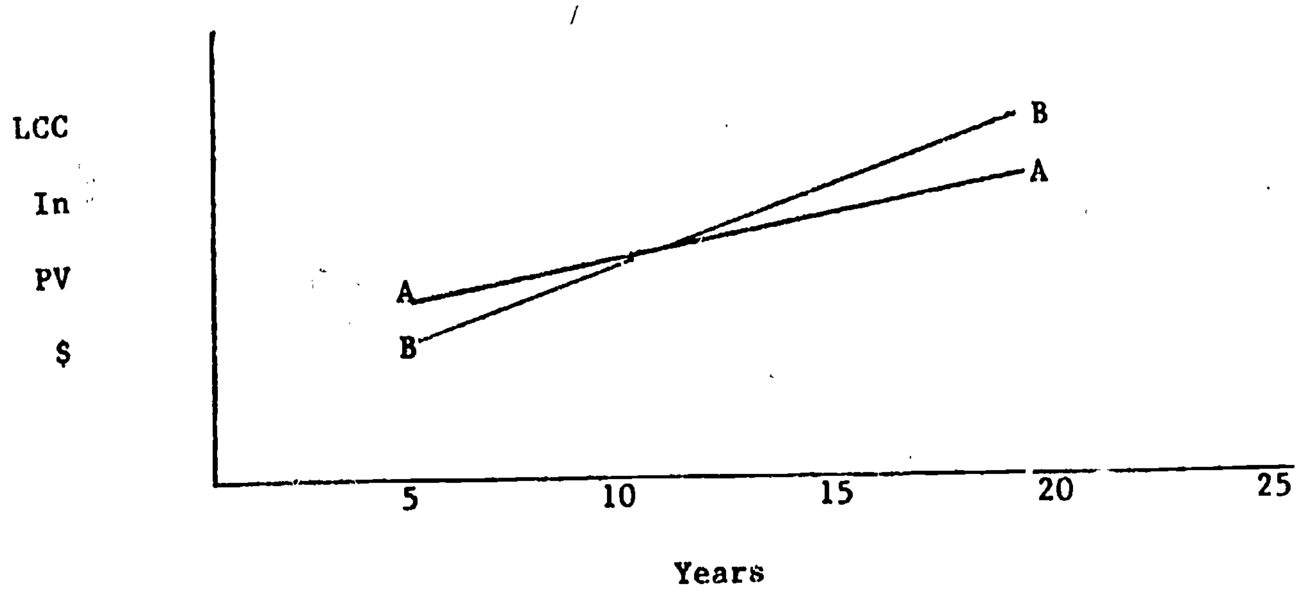
Figure 6-2 illustrates the sensitivity of present value energy savings to the rate of energy escalation. Given a fixed discount rate of 7 percent and no escalation, present value savings rise only slightly over time. But as the escalation rate increases to 7 percent and then 14 percent, the present value savings rise sharply over time.

References:

See Workbook Section 13, Problem Set C, "Sensitivity Analysis Problem: Insulation," and Workbook Section 12, Problem Set B, "Computer Room Waste Heat Recovery Problem."

Figure 6-1 Sensitivity Analysis

Time Horizon



A = Project A

B = Project B

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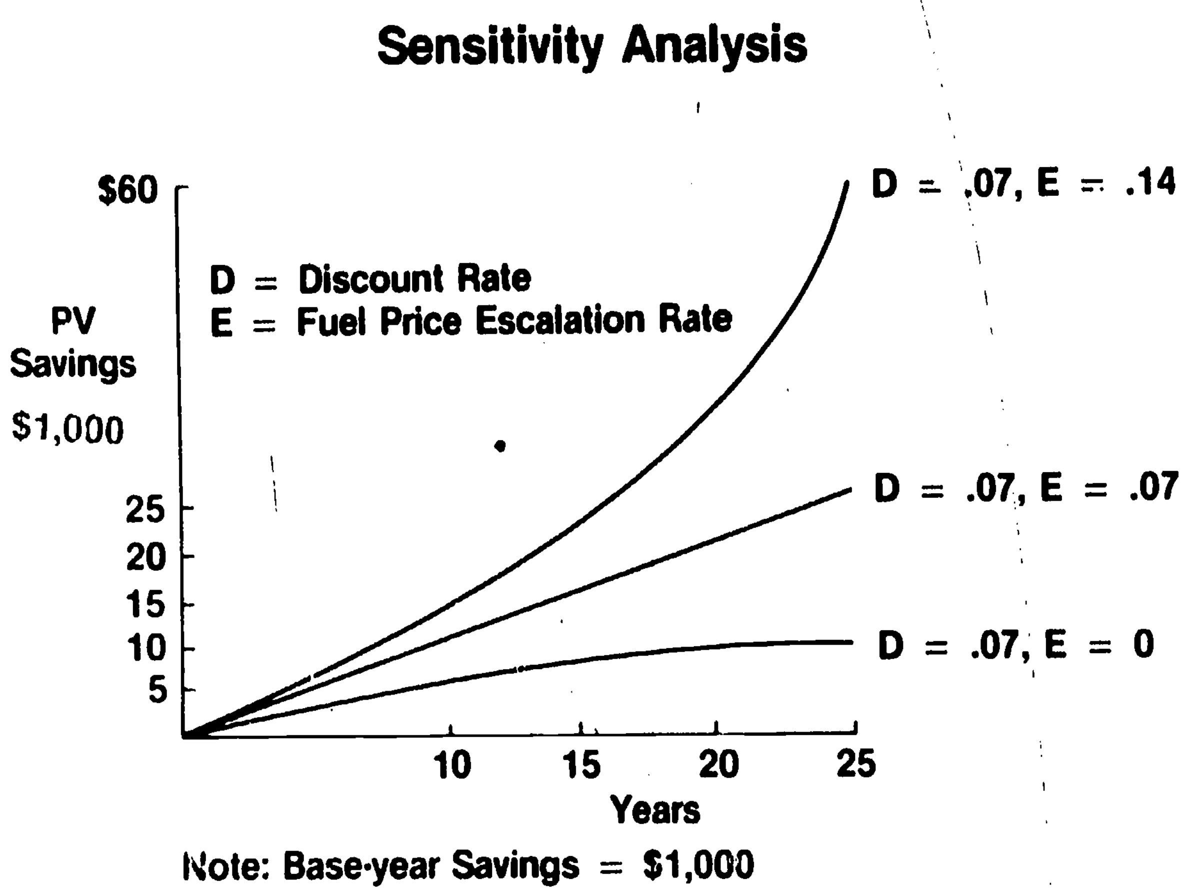
Figure 6-2


Sensitivity Analysis
$60
PV
Savings
$1,000
25
20
15
10
5
D = Discount Rate
E = Fuel Price Escalation Rate
D = .07, E = .14
D = .07, E = .07
D = .07, E = 0
10
15
20
25
Years
Note: Base-year Savings = $1,000

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Section 7

Probability Analysis

Probability analysis is another technique for taking into account uncertainty in economic evaluations. It relies on the use of probabilities rather than repetition of the evaluation. Probability analysis is a useful approach when (a) there is more than one possible condition, or "state of nature," which can occur, (b) the project outcome may differ depending on the state that occurs, and (c) the probability, or relative frequency, with which each possible state is expected to occur can be used to calculate the average, or "expected," value of possible outcomes weighted according to their frequency of occurrence. The following four sections provide a brief treatment of the topic:

(1) Approach

(2) Problem Illustration--Calculating Expected Values

(3) Decision Trees

(4) Computer Simulations

Approach

(1) List the alternative courses ~~of~~ action under consideration for which a decision is to be made. For example, which of two project alternatives, Project A or Project B, should be selected?

(2) List the possible states which may be significant to the project decision. For example, a component may function without failure (state 1), or it may fail during the project study period (state 2).

(3) For each state, estimate in turn the outcome if that state occurred and each of the alternative courses of action were taken. For example, what is the estimated life-cycle cost of Project A if state 1 occurs; what is the life-cycle cost of Project B if state 1 occurs; and what are the life-cycle costs of each project if state 2 occurs? [Note that this is in effect sensitivity analysis using the conventional evaluation techniques considered previously.]

(4) For each possible state, it can now be determined which course of action would be best if it were known with certainty that the state in question would occur. Project B might be found to be the more cost-effective project if state 1 occurred with certainty, and Project A the more cost-effective project if state 2 occurred with certainty. [Note that one course of action might be preferred, or "dominant," for all states, in which case the desired course of action is clear. This means that the decision is <u>not</u> sensitive to the state which occurs. But if the best course of action <u>does</u> depend on the state that occurs, further analysis is required as described in steps 5-7 below.]

(5) Assign a probability to the likely occurrence of each state, making sure that the probabilities of all of the states sum to 1.0. (The previous statement assumes one and only one of the states occurs). For example, state 1, no component failure, may be expected to occur 60 percent of the time, and state 2, failure, 40 percent of the time. [Note that these probabilities may be based on statistical observation of the frequency of failure in like or similar components, or they may be based on a measure of the degree of belief that the respective states will occur.]

(6) Calculate the expected value of each course of action. This is done for a course of action by multiplying the value which would result from that course of action under each state of nature by the probability that the state of nature will occur, and summing the results. For example,

$$EV_A = p_1 x_{A1} + p_2 x_{A2} + \dots + p_n x_{An} ,$$

where EV_A = expected value of a given course of action, A,

p_n = the probability of a given state occurring, where the subscript indicates states 1 to n, and

x_{An} = the estimated value associated with the given course of action, A, if the state designated by the subscript n were to occur with certainty.

(7) Choose the course of action according to the expected value criterion, i.e., minimize the expected value of cost or maximize the expected value of net benefits. This decision process, based on expected values, is illustrated in the hypothetical example which follows.

Problem Illustration--Calculating Expected Values

[Note: This is a hypothetical problem intended only to illustrate the technique.]

The problem is whether or not to install an emergency power generator for refrigerated storage in a Federal warehouse facility. The generator costs \$5,000 to purchase and install, and is expected to have no other significant costs over its estimated 10 year life. Two courses of action are to be considered: Course A, do not install the generator; and Course B, install the generator.

The rationale for installing the emergency generator is to protect against losses of stored goods which will result if there is a power failure lasting more than four hours. Based on past experience, the electric utility predicts the probability of a single occurrence within the period of a year of power failure exceeding four hours to be .005. The Federal agency estimates the value of losses per event of major power failure to be \$50,000 without the generator, and \$0 with the generator.

The decision maker wishes to make the decision on the basis of minimizing the expected value of the overall cost of the operation. Should the generator be installed? (Assume that a 10 percent discount rate applies.)

SOLUTION

Table 7-1. Annualized Cost of Alternative Actions Under Possible States of Nature

Courses of Action	Annualized Cost, Given State: State 1 No Power Failure ($p = .995$)	State 2 Power Failure ($p = .005$)
A (Do Not Install Generator)	$0	$50,000
B (Install Generator)	$815[a]	$815[a]

[a] The annualized cost of installing the generator is $5,000 x .163 = $815, where $5,000 is the initial cost and .163 is the Uniform Capital Recovery Factor for 10 years and 10 percent.

Expected Value Calculations:

$$EV_A = [(0)\ (.995)] + [(\$50,000)\ (.005)]$$

$$= \$250.$$

$$EV_B = [(\$5,000)\ (.163)\ (.995)] + [(\$5,000)\ (.163)\ (.005)]$$

$$= \$815.$$

(Note that EV_B can be found simply as ($5,000)(.163), because according to problem assumptions the cost of installing the generator is $5,000 regardless of the state. The calculation is shown broken down into elements for each state of nature to portray the more general case. For example, if a power failure would result in partial losses despite the installation of the generator, then the cost of Action B would be a function of the State of Nature.)

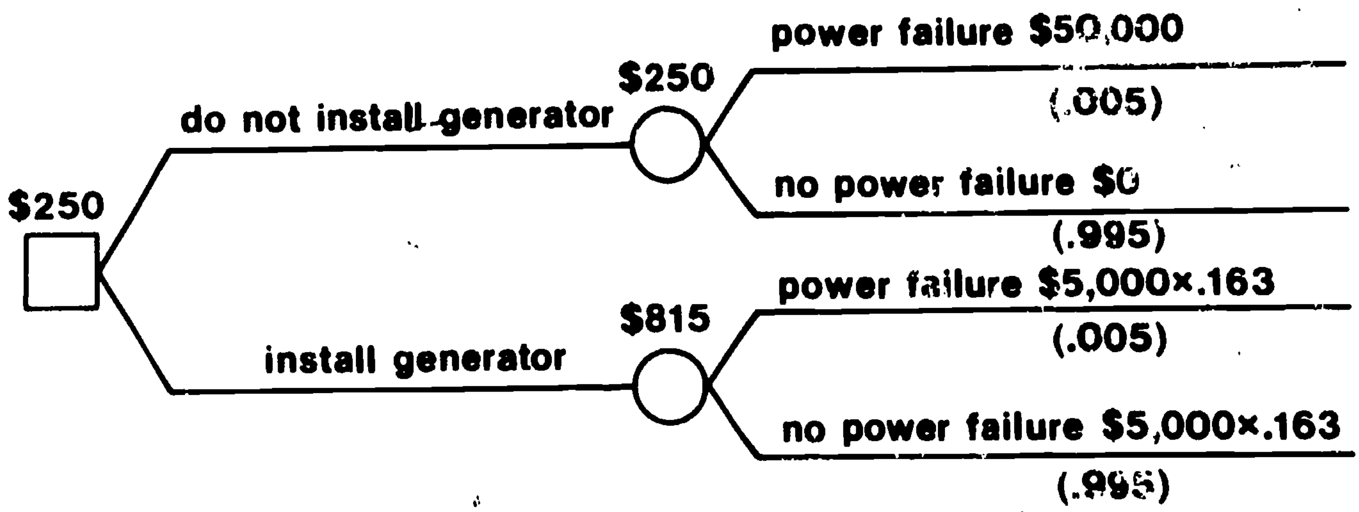
Decision:

Do not install the emergency generator.

Decision Trees

Decision trees are useful schematic forms for depicting in a decision framework alternative outcomes resulting from probabilistic events. A decision tree for the illustrative problem is shown below. Decision trees are constructed from left to right and are analyzed from right to left. Boxes are used to indicate controllable (decision) points and circles for uncontrollable (chance) events.

DECISION TREE



Computer Simulation

Computer simulation is generally required when probability distributions are used for a number of input values. The computer is programmed to select a value at random from each of the input distributions, and to compute a measure of economic performance (such as net savings) for each set of data so selected. This operation is repeated many times, generating a probability distribution of the output. Statistical analysis of the output distribution can then be used to provide the decision maker with a measure of the degree of dispersion, the risk associated with the project, as well as the expected value.

Reference: See Workbook Section 13, Problem Set C, "Problem in Probability Analysis: Heat Pump Versus Solar Energy System."

Section 8

Break-Even Analysis

Break-even analysis is a technique used to solve for the value of a selected parameter which will equate benefits and costs. It is useful in a variety of decision making applications, usually in a supporting or supplementary role to other evaluation techniques. This section provides a brief introduction to the use of break-even analysis in the following three parts:

(1) Approach

(2) Applications

(3) Break-Even Analysis Problem Illustration: Make-Buy Decision

Approach

Select a critical parameter, the value of which is uncertain, and treat that parameter as an unknown. Construct an equation which sets present value benefits equal to present value costs (or the costs of alternatives equal to one another, depending on the nature of the problem), entering into the equation the unknown parameter. Solve for the value of the parameter. The solution value is the minimum or maximum value which that parameter can take and still have the project be minimally cost effective. For example, the break-even purchase and installation cost would indicate the maximum amount that a project could cost initially and be minimally acceptable, other things being equal. To evaluate project acceptability, the decision maker must consider the likelihood that the actual value of the parameter will be greater or less than the solution value.

Applications

One type of application for the break-even technique is in making decisions that result in the substitution of costs that are relatively fixed for costs that are relatively variable. Examples include decisions to own versus to lease buildings and equipment; to produce an item internally versus to buy it outside; and to use labor-intensive versus capital-intensive production techniques.

Break-even analysis is useful to address the problem of uncertainty associated with many different kinds of projects by helping to establish the boundaries within which a project will be cost effective. For example, the technique can be used to find break-even investment cost, break-even energy savings, break-even system life, and the minimum or maximum required value of practically any other parameter critical to project success.

The break-even technique is widely used by private business to estimate the minimum requirements necessary for successful operations, such as the minimum sales required to cover total costs.

Break-Even Analysis Problem Illustration: Make-Buy Decision

[Note: This hypothetical problem is intended only to illustrate the technique.]

Problem Statement: A temporary Federal facility in Pennsylvania, now in the planning stage, will have a demand for steam. But at this time only a very rough estimate of the quantity demanded is available.

An outside source has expressed interest in supplying the steam requirements at an initial price (PP) of $10.00 per Mlb of steam supplied at the building boundary, with a subsequent annual escalation of price equal to the annual change in the GNP price deflator index plus 5 percent. The source appears reliable and compatible with other aspects of the facility's plan.

Preliminary estimates of the administrative, space, equipment, and maintenance costs required for in-house production are as follows:

Allocated Space (S): $20,000

Administrative (A): $10,000/yr.

Equipment, Purchase and Installation (E): $200,000

Equipment, Maintenance (M): $5,000/yr.

(These are rough estimates because they are dependent to some extent on the quantity of steam to be generated which is not known at this time. However, the cost analyst thinks the cost estimates are relatively accurate because of the large element of fixed costs involved.)

Additional information required to determine the cost of in-house production is as follows:

Price of Coal per ton (PC): \$45.00

Anticipated Plant Efficiency (Eff): 65%

Required Length of Service (N): 8 years

Anticipated Salvage at the End of 8 Years ($\overline{S}$): 0

Btu Content per Thousand Pounds (Mlb) of Steam: 1.05×10^6Btu

Btu Content per Ton of Coal: 22.5×10^6Btu

The facility planners are trying to decide whether to recommend that the steam requirements be met through the outside supplier or by in-house production. They believe life-cycle cost differences should be the deciding factor. However, they are having difficulty with this comparison due to the uncertainty regarding the amount of steam that will be demanded.

To do:

Assist them with their decision by estimating the minimum quantity of annual steam demand necessary for cost-effective in-house production.

Solution:

Step 1. Equate the cost of purchase with the cost of production, entering the quantity of steam demanded as the unknown variable; i.e.,

$$PP \cdot ZMlb \cdot UPW^*_{8yr,7\%,5\%} = S + E + [(A+M) \cdot UPW_{8yr,7\%}] + \left[\frac{ZMlb \cdot 1.05\text{x}10^6 Btu/Mlb}{0.65 \cdot 22.5\text{x}10^6 Btu/ton} \cdot PC \cdot UPW^*_{8yr,7\%,DoE3}\right]$$

Step 2. Solve for break-even level of steam, Mlb; i.e.,

$$\$10.00 \cdot ZMlb \cdot \left(\frac{1+0.05}{0.07-0.05}\right)\left[1-\left(\frac{1+0.05}{1+0.07}\right)^8\right] = \$20,000 + \$200,000 + \left[(10,000+5,000)\cdot 5.97\right] + \left[\frac{ZMlb \cdot 1.05\times10^6 Btu/Mlb}{0.65 \cdot 22.5\times10^6 Btu/ton} \cdot \$45/ton \cdot 7.37\right]$$

$$\$73.56 \cdot ZMlb = \$220,000 + \$89,550 + 23.81\ ZMlb$$

$$\$49.75 \cdot ZMlb = \$309,550$$

$$Z = 6,222\ Mlb.$$

Step 3. Draw Conclusion, i.e.,

For cost-effective production of steam in-house, the annual demand must be greater than about 6,000 Mlb. Due to the large component of fixed cost for in-house steam production, less steam consumption could more economically be purchased from outside. Higher consumption, on the other hand, would help reduce the cost per pound for in-house production and thereby likely make it cheaper than the fixed price per pound of steam purchased from the outside.

References:

Other Problem Examples: See Workbook Section 12, Problem Set B, "Computer Room Waste Heat Recovery Problem," and Workbook Section 14, Problem Set D, "Team Problem--Break-Even Orders for a Computerized Procurement System."

Section 9

Replacement Decisions

Replacement Theory or Analysis is a methodology for finding the economic life, that is, the service interval for equipment and facilities for which life-cycle costs for a given level of service will be minimum or net benefits will be maximized. It is briefly treated here in the following two parts because replacement decisions go hand-in-hand with other project investment decisions:

(1) Approach

(2) Illustrative Problem: Determining Optimal Replacement of Like Equipment

Approach

The customary approach for determining the optimal service interval is to compute the annualized costs for different service intervals and select the interval that minimizes annual cost. For certain kinds of problems such as those involving relatively short, well-defined time periods, it may be more convenient to minimize present value costs.

Illustrative Problem: Determining Optimal Replacement of Like Equipment

[Note: This hypothetical example is intended only to illustrate the technique.]

Question: How frequently should a given piece of equipment (E_A) be replaced?

Data and Assumptions:

- Identical constant dollar costs (C) for present and future replacement units of E_A of $20,000
- Uniform benefits
- Long duration of service
- The following are resale values (S) and operation, maintenance, and repair costs (O+M+R) for each year the equipment is in service:

Year in Service	Resale Value (constant $)	O+M+R Cost (constant $)
1	12,000	2,000
2	10,000	3,000
3	8,000	4,000
4	6,000	5,000
5	2,000	6,000

Approach: Find the number of years until replacement (n) for which the annualized cost (AC(n)) is minimum, where

$$AC(n) = [C - (S(n) \times SPW(n)) + \sum_{j=1}^{n} [(O+M+R)_j \times SPW_j]] \times UCR(n)$$

Solution:

Step 1. Calculate annual costs for different values of n.

$$AC(n) = \left[C - \left(S(n) \times SPW(n)\right) + \sum_{j=1}^{n} \left[(O+M_j+R_j) \times SPW_j\right]\right] \left(UCR(n)\right)$$

$$AC(1) = \left[[\$20{,}000 - (12{,}000 \times 0.93)] + (2{,}000 \times 0.93)\right] (1.07) = \$11{,}449$$

$$AC(2) = \left[[\$20{,}000 - (10{,}000 \times 0.87)] + \left[(2{,}000 \times 0.93) + (3{,}000 \times 0.87)\right]\right] (0.553) = \$8{,}721$$

$$AC(3) = \left[[\$20{,}000 - (8{,}000 \times 0.82)] + [(2{,}000 \times 0.93) + (3{,}000 \times 0.87) + (4{,}000 \times 0.82)]\right] (0.381) = \$8{,}073$$

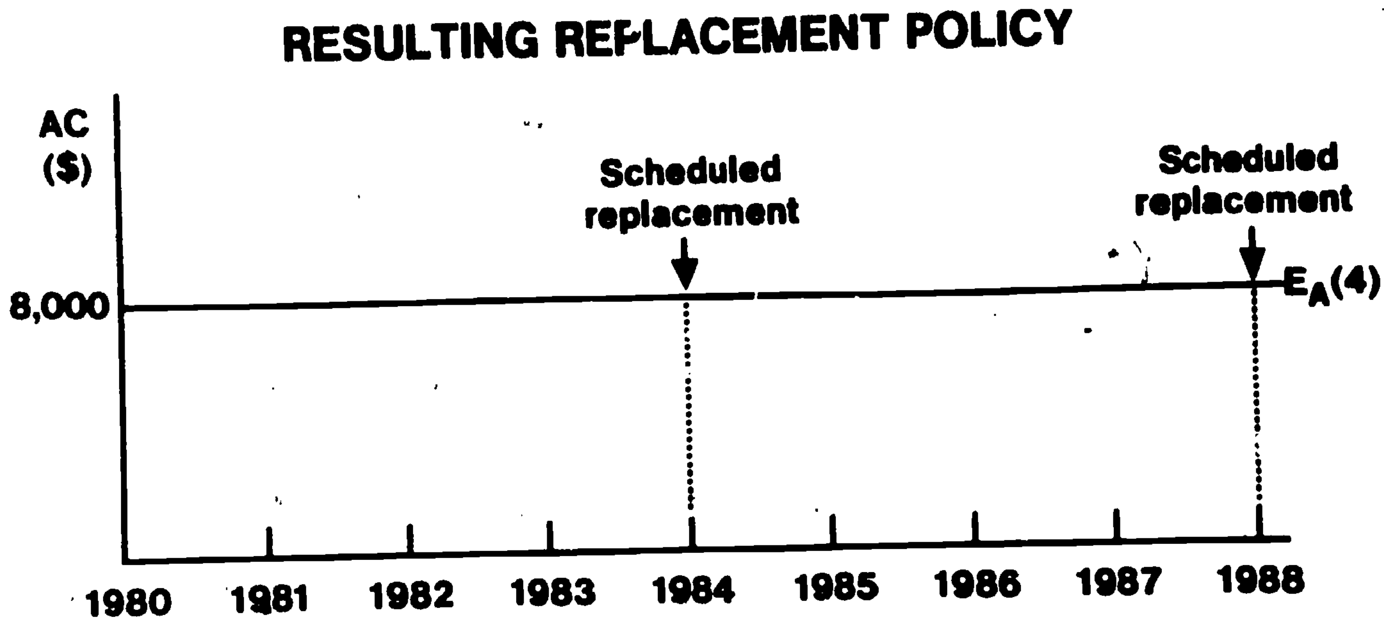
$$AC(4) = \left[[\$20{,}000 - (6{,}000 \times 0.76)] + [(2{,}000 \times 0.93) + (3{,}000 \times 0.87) + (4{,}000 \times 0.82) + (5{,}000 \times 0.76)]\right] (0.295) = \$7{,}962$$

$$AC(5) = \left[[\$20{,}000 - (2{,}000 \times 0.71)] + [(2{,}000 \times 0.93) + (3{,}000 \times 0.87) + (4{,}000 \times 0.82) + (5{,}000 \times 0.76) + (6{,}000 \times 0.71)]\right] (0.244) = \$8{,}391$$

Step 2. Compare the annual costs for different replacement times and identify the replacement time for which annual cost is lowest.

YEAR IN SERVICE	RESALE VALUE $	ANNUAL O&M COSTS $	EQUIVALENT ANNUAL COST $
0	20,000	0	0
1	12,000	2,000	11,449
2	10,000	3,000	8,721
3	8,000	4,000	8,073
4	6,000	5,000	7,962*
5	2,000	6,000	8,391

Step 3. Establish replacement schedule.



New Information: Now assume that it is approaching the scheduled time in 1984 for replacing the equipment (E_A), based on the preceding analysis. However, new information has been received that an improved piece of equipment (E_B) will be available in 1985. An analysis of E_B indicates that its annualized costs will be about $5,000 if it is replaced every six years. This new scenario is illustrated by figure 9-1.

Question: What decision do we make for 1984?

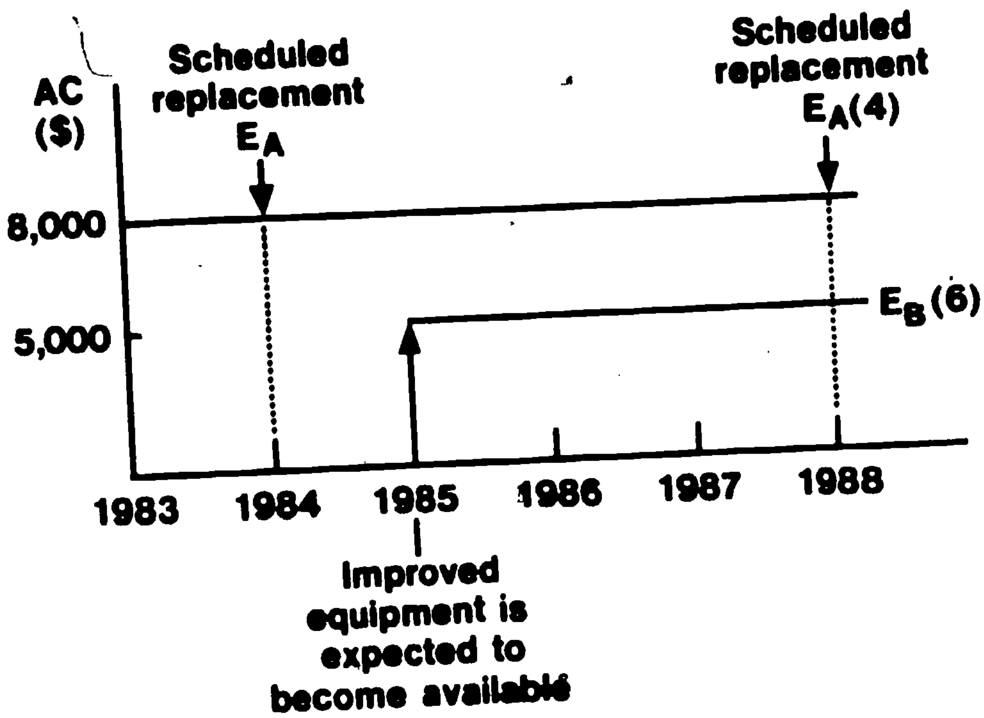
Approach: Identify alternative actions that might be taken, and compare present value costs for the period 1984-1988 under the alternative actions. Then select the action that is estimated to result in the lowest present value. (It is only necessary to consider the period 1984-1988, because the new equipment E_B will be introduced no later than 1988 and, once introduced, it will have a replacement schedule of every six years).

Solution: Three alternative actions are identified and their present value costs estimated, as shown in figure 9-2. The third action listed, "Keep existing equipment until 1985, then innovate," is estimated to be the cost-effective decision.

References: Also see Workbook Section 14, Problem Set D, "Team Problem: Determining Optimal Retirement of Equipment."

Figure 9-1

DETERMINING REPLACEMENT WITH UNLIKE EQUIPMENT



What decision do we make for 1984 ?

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Figure 9-2

SOLUTION: COMPARE PV COSTS FOR 1984-1988 UNDER ALTERNATIVES

- **Replace in 1984 with E_A and wait until 1988 to innovate**

(ACE$_A$ (N=4); UPW$_4$)

$$PV = \$8,000 \times 3.39 = \$27,120$$

- **Replace in 1984 with E_A and innovate in 1985**

(FIRST COST; RESALE(1); SPW$_1$; O&M(1); SPW$_1$; ACE$_B$ (N=6); UPW$_3$; SPW$_1$)

$$PV = [\$20,000 - (\$12,000 \times 0.93)] + (\$2,000 \times 0.93) + (\$5,000 \times 2.62 \times 0.93)$$
$$= \$22,883$$

- * **Keep existing equipment until 1985, then innovate**

(1984 RESALE; 1985 RESALE; SPW$_1$; 1984 O&M; SPW$_1$; ACE$_B$ (6); UPW$_3$; SPW$_1$)

$$PV = [\$6,000 - (\$2,000 \times 0.93)] + (\$6,000 \times 0.93) + [\$5,000 \times 2.62 \times 0.93]$$
$$= \$21,\text{[illegible]}03$$

*This is the decision that minimizes present value costs. After E_B is adopted in 1985, it would then be replaced every 6 years.

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Section 10

Worksheets

This section contains six sets of worksheets for solving retrofit building problems and one set for selecting among alternative new building designs. They are provided as aids in organizing the data and performing the calculations to solve problems presented in Sections 11 and 12. Problem 2 in Section 11 and problems 1 and 3 in Section 12 require one set of retrofit worksheets each. Problem 2 in Section 12 requires three sets of retrofit worksheets. Problem 3 in Section 11 uses the set of new building design worksheets.

RETROFIT LCC WORKSHEETS

Identifying Information

Building Description:

Location ________________________________

DoE Region ________________________________

Functional Use ________________________________

Building type ( ) Residential
( ) Commercial
( ) Industrial

Remaining Life of Building ________________________________

Project Description ________________________________

Expected Project Life ________________________________

Length of Study Period (Not to Exceed 25 years) ________________

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RETROFIT LCC WORKSHEET (Continued)

A. Calculating the Present Value of Energy Costs Without the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)= (3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)= (5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL					
GAS					
OTHER ____					
TOTAL	X	X	X	X	

B. Calculating Investment Costs for the Existing System Without the Retrofit

(1) Base-Year Resale, Salvage, or Reuse Value of the Existing System to be Replaced $ ______

(2) Base-Year Renovation Costs for the Existing System if the Retrofit Project is <u>Not</u> Implemented $ ______

C. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1)x(2)= (3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

D. Calculating Nonannually Recurring O&M (Nonfuel) Costs, Replacement Costs, and Salvage Value Without the Retrofit.

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECCURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)x(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)x(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)x(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

E. Calculating TLCC Without the Retrofit

(1) Present Value of Energy Costs : A(5) Total $ ____

(2) Present Value of Investment Costs : B(1) or (2) + $ ____

(3) Present Value of Annually Recurring (Nonfuel) O&M Costs : C(3) + $ ____

(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs: D(6) Total + $ ____

(5) Present Value of Replacement Costs ; D(7) Total + $ ____

(6) Present Value of Salvage : D(8) Total - $ ____

(7) TLCC Without the Retrofit: (1)+(2)+(3)+(4)+(5)-(6) = $ ____

[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occur in 1990 and you are using 1982 as the base year, base-year dollars means stating the 1990 costs in 1982 dollars, i.e., without future inflation.

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)= (3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)= (5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE $ ______ DEMAND CHARGE $ ______ TIME OF DAY CHARGE $ ______ CONTRACT CAPACITY CHARGE $ ______ OTHER CHARGE COMPONENT	______	$ ______ $ ______ $ ______ $ ______ $ ______
OIL					
GAS					
OTHER ______					
TOTAL	X	X	X	X	

G. Calculating Investment Costs with the Retrofit

(1) Estimated Actual Investment Costs for the Retrofit Project ______

(2) Investment Cost Adjustment Factor x ______

(3) Adjusted Investment Costs for the Retrofit Project : (1)x(2) = ______

(4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented + ______

(5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project: (3)+(4) = ______

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H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1)x(2)= (3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)x(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)x(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)x(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

J. Calculating TLCC With the Retrofit Project

(1) Present Value of Energy Costs: F(5) Total ______

(2) Present Value of Adjusted Investment Costs: G(5) + ______

(3) Present Value of Annually Recurring (Nonfuel) O&M Costs: H(3) + ______

(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs: I(6) Total + ______

(5) Present Value of Replacement Costs: I(7) Total + ______

(6) Present Value of Salvage: I(8) Total - ______

(7) TLCC With the Retrofit Project: (1)+(2)+(3)+(4)+(5)-(6) = ______

[1] See footnote on Part D for explanation.

K. Net Savings or Excess Cost of the Retrofit Project

(1) TLCC without the Retrofit : E(7)		$ ______
(2) TLCC with the Retrofit : J(7)	-	$ ______
(3) Net Savings (+) or net losses (-) : (1)-(2)	= (+)	$ ______

L. SIR Calculation

(1) SIR Numerator		
(a) Energy Cost Savings from the Retrofit : E(1)-J(1)		$ ______
(b) Change in Nonfuel O&M Costs : [J(3)+(4)]-[E(3)+(4)]	-	$ ______
(c) SIR Numerator : (a)-(b)	=	$ ______
(2) SIR Denominator		
(a) Adjusted Differential Investment Cost : J(2)-E(2)		$ ______
(b) Change in Replacement Costs : J(5)-E(5)	+	$ ______
(c) Change in Salvage Value : J(6)-E(6)	-	$ ______
(d) SIR Denominator : (a)+(b)-(c)	=	$ ______
(3) SIR for Ranking the Retrofit Project : (1)(c)÷(2)(d)		______

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RETROFIT LCC WORKSHEETS

Identifying Information

Building Description:

Location ______________________________

DoE Region ______________________________

Functional Use ______________________________

Building type ( ) Residential
( ) Commercial
( ) Industrial

Remaining Life of Building ______________________________

Project Description ______________________________

Expected Project Life ______________________________

Length of Study Period (Not to Exceed 25 years) ______________________________

A. Calculating the Present Value of Energy Costs Without the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)= (3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)= (5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	________	________	$ ________ BASE CHARGE	________	$ ________
			$ ________ DEMAND CHARGE		$ ________
			$ ________ TIME OF DAY CHARGE		$ ________
			$ ________ CONTRACT CAPACITY CHARGE		$ ________
			$ ________ OTHER CHARGE COMPONENT		$ ________
OIL					
GAS					
OTHER ____					
TOTAL	X	X	X	X	

B. Calculating Investment Costs for the Existing System Without the Retrofit

(1) Base-Year Resale, Salvage, or Reuse Value of the Existing System to be Replaced $ ______

(2) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Not Implemented $ ______

C. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1)x(2)= (3) Present Value of Annually Recurring Costs
$ ________	________	$ ________

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D. Calculating Nonannually Recurring O&M (Nonfuel) Costs, Replacement Costs, and Salvage Value Without the Retrofit.

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECCURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)x(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)x(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)x(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

E. Calculating TLCC Without the Retrofit

(1)	Present Value of Energy Costs : A(5) Total		$ ______
(2)	Present Value of Investment Costs : B(1) or (2)	+	$ ______
(3)	Present Value of Annually Recurring (Nonfuel) O&M Costs : C(3)	+	$ ______
(4)	Present Value of Nonannually Recurring (Nonfuel) O&M Costs: D(6) Total	+	$ ______
(5)	Present Value of Replacement Costs : D(7) Total	+	$ ______
(6)	Present Value of Salvage : D(8) Total	-	$ ______
(7)	TLCC Without the Retrofit: (1)+(2)+(3)+(4)+(5)-(6)	=	$ ______

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[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occur in 1990 and you are using 1982 as the base year, base-year dollars means stating the 1990 costs in 1982 dollars, i.e., without future inflation.

RETROFIT LCC WORKSHEETS (Continued)

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)= (3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)= (5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL					
GAS					
OTHER ______					
TOTAL	X	X	X	X	

G. Calculating Investment Costs with the Retrofit

(1) Estimated Actual Investment Costs for the Retrofit Project ______

(2) Investment Cost Adjustment Factor x ______

(3) Adjusted Investment Costs for the Retrofit Project : (1)x(2) = ______

(4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented + ______

(5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project: (3)+(4) = ______

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H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1)×(2)= (3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)×(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)×(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)×(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

J. Calculating TLCC With the Retrofit Project

(1) Present Value of Energy Costs: F(5) Total ______

(2) Present Value of Adjusted Investment Costs: G(5) + ______

(3) Present Value of Annually Recurring (Nonfuel) O&M Costs: H(3) + ______

(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs: I(6) Total + ______

(5) Present Value of Replacement Costs: I(7) Total + ______

(6) Present Value of Salvage: I(8) Total - ______

(7) TLCC With the Retrofit Project: (1)+(2)+(3)+(4)+(5)-(6) = ______

[1] See footnote on Part D for explanation.

K. Net Savings or Excess Cost of the Retrofit Project

(1) TLCC without the Retrofit : E(7)		$	______
(2) TLCC with the Retrofit : J(7)	-	$	______
(3) Net Savings (+) or net losses (-) : (1)-(2)	= (+)	$	______

L. SIR Calculation

(1) SIR Numerator			
(a) Energy Cost Savings from the Retrofit : E(1)-J(1)		$	______
(b) Change in Nonfuel O&M Costs : [J(3)+(4)]-[E(3)+(4)]	-	$	______
(c) SIR Numerator : (a)-(b)	=	$	______
(2) SIR Denominator			
(a) Adjusted Differential Investment Cost : J(2)-E(2)		$	______
(b) Change in Replacement Costs : J(5)-E(5)	+	$	______
(c) Change in Salvage Value : J(6)-E(6)	-	$	______
(d) SIR Denominator : (a)+(b)-(c)	=	$	______
(3) SIR for Ranking the Retrofit Project : (1)(c)÷(2)(d)			______

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RETROFIT LCC WORKSHEETS

Identifying Information

Building Description:

Location ______________________________

DoE Region ______________________________

Functional Use ______________________________

Building type ( ) Residential
( ) Commercial
( ) Industrial

Remaining Life of Building ______________________________

Project Description ______________________________

Expected Project Life ______________________________

Length of Study Period (Not to Exceed 25 years) ______________

A. Calculating the Present Value of Energy Costs Without the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)= (3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)= (5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL					
GAS					
OTHER ____					
TOTAL	X	X	X	X	

B. Calculating Investment Costs for the Existing System Without the Retrofit

(1) Base-Year Resale, Salvage, or Reuse Value of the Existing System to be Replaced $ ______

(2) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Not Implemented $ ______

C. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1)x(2)= (3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

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D. Calculating Nonannually Recurring O&M (Nonfuel) Costs, Replacement Costs, and Salvage Value Without the Retrofit.

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)x(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)x(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)x(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

E. Calculating TLCC Without the Retrofit

(1) Present Value of Energy Costs: A(5) Total		$ ______
(2) Present Value of Investment Costs: B(1) or (2)	+	$ ______
(3) Present Value of Annually Recurring (Nonfuel) O&M Costs: C(3)	+	$ ______
(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs: D(6) Total	+	$ ______
(5) Present Value of Replacement Costs: D(7) Total	+	$ ______
(6) Present Value of Salvage: D(8) Total	-	$ ______
(7) TLCC Without the Retrofit: (1)+(2)+(3)+(4)+(5)-(6)	=	$ ______

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[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occur in 1990 and you are using 1982 as the base year, base-year dollars means stating the 1990 costs in 1982 dollars, i.e., without future inflation.

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)= (3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)= (5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL					
GAS					
OTHER ______					
TOTAL	X	X	X	X	

G. Calculating Investment Costs with the Retrofit

(1) Estimated Actual Investment Costs for the Retrofit Project		______
(2) Investment Cost Adjustment Factor	x	______
(3) Adjusted Investment Costs for the Retrofit Project : (1)x(2)	=	______
(4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented	+	______
(5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project: (3)+(4)	=	______

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H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1)x(2)= (3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)x(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)x(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)x(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

J. Calculating TLCC With the Retrofit Project

(1) Present Value of Energy Costs: F(5) Total ______

(2) Present Value of Adjusted Investment Costs: G(5) + ______

(3) Present Value of Annually Recurring (Nonfuel) O&M Costs: H(3) + ______

(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs: I(6) Total + ______

(5) Present Value of Replacement Costs: I(7) Total + ______

(6) Present Value of Salvage: I(8) Total - ______

(7) TLCC With the Retrofit Project: (1)+(2)+(3)+(4)+(5)-(6) = ______

[1] See footnote on Part D for explanation.

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K. Net Savings or Excess Cost of the Retrofit Project

(1) TLCC without the Retrofit : E(7)		$	______
(2) TLCC with the Retrofit : J(7)	-	$	______
(3) Net Savings (+) or net losses (-) : (1)-(2)	= (+)	$	______

L. SIR Calculation

(1) SIR Numerator			
(a) Energy Cost Savings from the Retrofit : E(1)-J(1)		$	______
(b) Change in Nonfuel O&M Costs : [J(3)+(4)]-[E(3)+(4)]	-	$	______
(c) SIR Numerator : (a)-(b)	=	$	______
(2) SIR Denominator			
(a) Adjusted Differential Investment Cost : J(2)-E(2)		$	______
(b) Change in Replacement Costs : J(5)-E(5)	+	$	______
(c) Change in Salvage Value : J(6)-E(6)	-	$	______
(d) SIR Denominator : (a)+(b)-(c)	=	$	______
(3) SIR for Ranking the Retrofit Project : (1)(c)÷(2)(d)			______

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RETROFIT LCC WORKSHEETS

Identifying Information

Building Description:

Location ______________________________

DoE Region ______________________________

Functional Use ______________________________

Building type ( ) Residential
( ) Commercial
( ) Industrial

Remaining Life of Building ______________________________

Project Description ______________________________

Expected Project Life ______________________________

Length of Study Period (Not to Exceed 25 years) ______________

A. Calculating the Present Value of Energy Costs Without the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)= (3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)= (5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL					
GAS					
OTHER ______					
TOTAL	X	X	X	X	

B. Calculating Investment Costs for the Existing System Without the Retrofit

(1) Base-Year Resale, Salvage, or Reuse Value of the Existing System to be Replaced $ ______

(2) Base-Year Renovation Costs for the Existing System if the Retrofit Project is <u>Not</u> Implemented $ ______

C. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1)x(2)= (3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

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D. Calculating Nonannually Recurring O&M (Nonfuel) Costs, Replacement Costs, and Salvage Value Without the Retrofit.

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECCURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)x(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)x(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)x(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

E. Calculating TLCC Without the Retrofit

(1) Present Value of Energy Costs: A(5) Total			$ ______
(2) Present Value of Investment Costs: B(1) or (2)		+	$ ______
(3) Present Value of Annually Recurring (Nonfuel) O&M Costs: C(3)		+	$ ______
(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs: D(6) Total		+	$ ______
(5) Present Value of Replacement Costs: D(7) Total		+	$ ______
(6) Present Value of Salvage: D(8) Total		−	$ ______
(7) TLCC Without the Retrofit: (1)+(2)+(3)+(4)+(5)−(6)		=	$ ______

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[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occur in 1990 and you are using 1982 as the base year, base-year dollars means stating the 1990 costs in 1982 dollars, i.e., without future inflation.

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)= (3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)= (5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL					
GAS					
OTHER ______					
TOTAL	X	X	X	X	

G. Calculating Investment Costs with the Retrofit

(1) Estimated Actual Investment Costs for the Retrofit Project ______

(2) Investment Cost Adjustment Factor x ______

(3) Adjusted Investment Costs for the Retrofit Project : (1)x(2) = ______

(4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented + ______

(5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project: (3)+(4) = ______

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H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1)x(2)= (3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)x(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)x(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)x(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

J. Calculating TLCC With the Retrofit Project

(1) Present Value of Energy Costs: F(5) Total ______

(2) Present Value of Adjusted Investment Costs: G(5) + ______

(3) Present Value of Annually Recurring (Nonfuel) O&M Costs: H(3) + ______

(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs: I(6) Total + ______

(5) Present Value of Replacement Costs: I(7) Total + ______

(6) Present Value of Salvage: I(8) Total - ______

(7) TLCC With the Retrofit Project: (1)+(2)+(3)+(4)+(5)-(6) = ______

[1] See footnote on Part D for explanation.

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K. Net Savings or Excess Cost of the Retrofit Project

(1) TLCC without the Retrofit : E(7)		$ ______
(2) TLCC with the Retrofit ; J(7)	−	$ ______
(3) Net Savings (+) or net losses (−) ; (1)−(2)	= (+)	$ ______

L. SIR Calculation

(1) SIR Numerator		
(a) Energy Cost Savings from the Retrofit : E(1)−J(1)		$ ______
(b) Change in Nonfuel O&M Costs ; [J(3)+(4)]−[E(3)+(4)]	−	$ ______
(c) SIR Numerator : (a)−(b)	=	$ ______
(2) SIR Denominator		
(a) Adjusted Differential Investment Cost : J(2)−E(2)		$ ______
(b) Change in Replacement Costs ; J(5)−E(5)	+	$ ______
(c) Change in Salvage Value ; J(6)−E(6)	−	$ ______
(d) SIR Denominator : (a)+(b)−(c)	=	$ ______
(3) SIR for Ranking the Retrofit Project : (1)(c)÷(2)(d)		______

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RETROFIT LCC WORKSHEETS

Identifying Information

Building Description:

Location ______________________________

DoE Region ______________________________

Functional Use ______________________________

Building type ( ) Residential
( ) Commercial
( ) Industrial

Remaining Life of Building ______________________________

Project Description ______________________________

Expected Project Life ______________________________

Length of Study Period (Not to Exceed 25 years) ______________

A. Calculating the Present Value of Energy Costs Without the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)= (3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)= (5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL					
GAS					
OTHER ______					
TOTAL	X	X	X	X	

B. Calculating Investment Costs for the Existing System Without the Retrofit

(1) Base-Year Resale, Salvage, or Reuse Value of the Existing System to be Replaced $ ______

(2) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Not Implemented $ ______

C. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1)x(2)= (3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

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D. Calculating Nonannually Recurring O&M (Nonfuel) Costs, Replacement Costs, and Salvage Value Without the Retrofit.

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECCURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)x(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)x(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)x(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

E. Calculating TLCC Without the Retrofit

(1) Present Value of Energy Costs : A(5) Total		$ ______
(2) Present Value of Investment Costs : B(1) or (2)	+	$ ______
(3) Present Value of Annually Recurring (Nonfuel) O&M Costs : C(3)	+	$ ______
(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs: D(6) Total	+	$ ______
(5) Present Value of Replacement Costs : D(7) Total	+	$ ______
(6) Present Value of Salvage : D(8) Total	-	$ ______
(7) TLCC Without the Retrofit: (1)+(2)+(3)+(4)+(5)-(6)	=	$ ______

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[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occur in 1990 and you are using 1982 as the base year, base-year dollars means stating the 1990 costs in 1982 dollars, i.e., without future inflation.

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)=(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)=(5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE $ ______ DEMAND CHARGE $ ______ TIME OF DAY CHARGE $ ______ CONTRACT CAPACITY CHARGE $ ______ OTHER CHARGE COMPONENT	______	$ ______ $ ______ $ ______ $ ______ $ ______
OIL					
GAS					
OTHER ____					
TOTAL	X	X	X	X	

G. Calculating Investment Costs with the Retrofit

(1) Estimated Actual Investment Costs for the Retrofit Project ______

(2) Investment Cost Adjustment Factor x ______

(3) Adjusted Investment Costs for the Retrofit Project : (1)x(2) = ______

(4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented + ______

(5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project: (3)+(4) = ______

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H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1) x (2) = (3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2) x (5) = (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3) x (5) = (7) PRESENT VALUE OF REPLACEMENT	(4) x (5) = (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

J. Calculating TLCC With the Retrofit Project

(1) Present Value of Energy Costs: F(5) Total ______

(2) Present Value of Adjusted Investment Costs: G(5) + ______

(3) Present Value of Annually Recurring (Nonfuel) O&M Costs: H(3) + ______

(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs: I(6) Total + ______

(5) Present Value of Replacement Costs: I(7) Total + ______

(6) Present Value of Salvage: I(8) Total - ______

(7) TLCC With the Retrofit Project: (1)+(2)+(3)+(4)+(5)-(6) = ______

[1] See footnote on Part D for explanation.

K. Net Savings or Excess Cost of the Retrofit Project

(1) TLCC without the Retrofit : E(7)		$	______
(2) TLCC with the Retrofit : J(7)	-	$	______
(3) Net Savings (+) or net losses (-) ; (1)-(2)	= (+)	$	______

L. SIR Calculation

(1) SIR Numerator			
(a) Energy Cost Savings from the Retrofit : E(1)-J(1)		$	______
(b) Change in Nonfuel O&M Costs : [J(3)+(4)]-[E(3)+(4)]	-	$	______
(c) SIR Numerator : (a)-(b)	=	$	______
(2) SIR Denominator			
(a) Adjusted Differential Investment Cost : J(2)-E(2)		$	______
(b) Change in Replacement Costs ; J(5)-E(5)	+	$	______
(c) Change in Salvage Value ; J(6)-E(6)	-	$	______
(d) SIR Denominator : (a)+(b)-(c)	=	$	______
(3) SIR for Ranking the Retrofit Project : (1)(c)÷(2)(d)			______

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RETROFIT LCC WORKSHEETS

Identifying Information

Building Description:

Location ________________________________

DoE Region ________________________________

Functional Use ________________________________

Building type ( ) Residential
( ) Commercial
( ) Industrial

Remaining Life of Building ________________________________

Project Description ________________________________

Expected Project Life ________________________________

Length of Study Period (Not to Exceed 25 years) ________________

A. Calculating the Present Value of Energy Costs Without the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)= (3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)= (5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL					
GAS					
OTHER ____					
TOTAL	X	X	X	X	

B. Calculating Investment Costs for the Existing System Without the Retrofit

(1) Base-Year Resale, Salvage, or Reuse Value of the Existing System to be Replaced $ ______

(2) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Not Implemented $ ______

C. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1)x(2)= (3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

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D. Calculating Nonannually Recurring O&M (Nonfuel) Costs, Replacement Costs, and Salvage Value Without the Retrofit.

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECCURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)×(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)×(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)×(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

E. Calculating TLCC Without the Retrofit

(1)	Present Value of Energy Costs: A(5) Total		$ ______
(2)	Present Value of Investment Costs: B(1) or (2)	+	$ ______
(3)	Present Value of Annually Recurring (Nonfuel) O&M Costs: C(3)	+	$ ______
(4)	Present Value of Nonannually Recurring (Nonfuel) O&M Costs: D(6) Total	+	$ ______
(5)	Present Value of Replacement Costs: D(7) Total	+	$ ______
(6)	Present Value of Salvage: D(8) Total	−	$ ______
(7)	TLCC Without the Retrofit: (1)+(2)+(3)+(4)+(5)-(6)	=	$ ______

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[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occur in 1990 and you are using 1982 as the base year, base-year dollars means stating the 1990 costs in 1982 dollars, i.e., without future inflation.

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)=(3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)=(5) PRESENT VALUE OF ENERGY COSTS
ELECTRICITY	______	______	$ ______ BASE CHARGE $ ______ DEMAND CHARGE $ ______ TIME OF DAY CHARGE $ ______ CONTRACT CAPACITY CHARGE $ ______ OTHER CHARGE COMPONENT	______	$ ______ $ ______ $ ______ $ ______ $ ______
OIL					
GAS					
OTHER ______					
TOTAL	X	X	X	X	

G. Calculating Investment Costs with the Retrofit

(1) Estimated Actual Investment Costs for the Retrofit Project ______

(2) Investment Cost Adjustment Factor x ______

(3) Adjusted Investment Costs for the Retrofit Project : (1)x(2) = ______

(4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented + ______

(5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project: (3)+(4) = ______

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H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(1)x(2)= (3) Present Value of Annually Recurring Costs
$ ______	______	$ ______

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)x(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)x(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)x(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

J. Calculating TLCC With the Retrofit Project

(1) Present Value of Energy Costs: F(5) Total ______

(2) Present Value of Adjusted Investment Costs: G(5) + ______

(3) Present Value of Annually Recurring (Nonfuel) O&M Costs: H(3) + ______

(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs: I(6) Total + ______

(5) Present Value of Replacement Costs: I(7) Total + ______

(6) Present Value of Salvage: I(8) Total - ______

(7) TLCC With the Retrofit Project: (1)+(2)+(3)+(4)+(5)-(6) = ______

[1] See footnote on Part D for explanation.

K. Net Savings or Excess Cost of the Retrofit Project

(1) TLCC without the Retrofit : E(7)		$ ______
(2) TLCC with the Retrofit : J(7)	-	$ ______
(3) Net Savings (+) or net losses (-) : (1)-(2)	= (+)	$ ______

L. SIR Calculation

(1) SIR Numerator		
(a) Energy Cost Savings from the Retrofit : E(1)-J(1)		$ ______
(b) Change in Nonfuel O&M Costs : [J(3)+(4)]-[E(3)+(4)]	-	$ ______
(c) SIR Numerator : (a)-(b)	=	$ ______
(2) SIR Denominator		
(a) Adjusted Differential Investment Cost : J(2)-E(2)		$ ______
(b) Change in Replacement Costs : J(5)-E(5)	+	$ ______
(c) Change in Salvage Value : J(6)-E(6)	-	$ ______
(d) SIR Denominator : (a)+(b)-(c)	=	$ ______
(3) SIR for Ranking the Retrofit Project : (1)(c)÷(2)(d)		______

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PROJECT SELECTION

Priority Ranking	Project	Project Cost	SIR	Net Savings
Totals			N.A.	

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NEW BUILDING DESIGN LCC WORKSHEETS

Identifying Information

Building Description:

Location ______________________________

DoE Region ______________________________

Functional Use ______________________________

Building type ( ) Residential
( ) Commercial
( ) Industrial

Project Description ______________________________

Expected Project Life ______________________________

Length of Study Period (Not to Exceed 25 years) ______________

A. Calculating the Present Value of Energy Costs

TYPE	(1) ANNUAL UNITS OF ENERGY PURCHASED	(2) BASE-YEAR ENERGY PRICE PER UNIT	(1)x(2)= (3) BASE-YEAR ENERGY COSTS	(4) UPW* FACTOR	(3)x(4)= (5) PRESENT VALUE OF ENERGY COST
ELECTRICITY	______	______	$ ______ BASE CHARGE	______	$ ______
			$ ______ DEMAND CHARGE		$ ______
			$ ______ TIME OF DAY CHARGE		$ ______
			$ ______ CONTRACT CAPACITY CHARGE		$ ______
			$ ______ OTHER CHARGE COMPONENT		$ ______
OIL					
GAS					
OTHER ______					
TOTAL	X	X	X	X	

B. Calculating Investment Costs for the New Building Design

(1) Estimated Actual Investment Costs for the New Building Design $ ______

(2) Investment Cost Adjustment Factor x ______

(3) Adjusted Investment Costs for the Retrofit Project; (1)x(2) = ______

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C. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs

(1) Amount of Annually Recurring Costs in Base Year	(2) UPW Factor	(3) (1)x(2)= Present Value of Annually Recurring Costs
$ ________	________	$ ________

D. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value

(1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR	(2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1]	(3) AMOUNT OF REPLACEMENT COST (IN BASE-YEAR $)[1]	(4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1]	(5) SPW FACTORS	(2)x(5)= (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS	(3)x(5)= (7) PRESENT VALUE OF REPLACEMENT	(4)x(5)= (8) PRESENT VALUE OF SALVAGE VALUE
TOTAL	X	X	X	X			

E. Calculating the TLCC

(1) Present Value Energy Costs: A(5) Total $ ________

(2) Present Value Adjusted Investment Costs: B(3) + $ ________

(3) Present Value of Annually Recurring (Nonfuel) O&M Costs: C(3) + $ ________

(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs: D(6) + $ ________

(5) Present Value of Replacement Costs: D(7) + $ ________

(6) Present Value of Salvage: D(8) - $ ________

(7) TLCC of the New Building or System Design: (1)+(2)+(3)+(4)+(5)-(6) = $ ________

1 For example, if nonannually recurring (nonfuel) O&M costs, replacement costs or salvage value occur in 1990 and you are using 1982 as the base year, base-year dollars means stating the 1990 costs in 1982 dollars, i.e., without future inflation.

Section 11

Problem Set A

This section contains simple discounting problems and simple building and energy conservation problems arranged in the following order:

(1) 6 Problems: Discounting and LCC Analysis Using Discount Factor Tables

(2) Programmable Time Clock Problem

(3) New Building Design Problem

Solutions to these problems are provided at the end of the section.

6 Problems: Discounting and LCC Analysis Using Discount Factor Tables

[These are hypothetical examples intended only to illustrate the techniques.]

1. What is the esti ated present value today to the Federal Government of a $10,000 cost to be incurred five years from now in conjunction with an energy conservation project? What is the equivalent annual value?

2. What is the estimated present value today to the Federal Government of a uniform annual cost of $1,000 (in constant dollars) that recurs over the next 20 years? (The cost stems from a renewable energy project). What is the equivalent annual value?

3. What is the estimated present value today of electricity costs for powering a motor in a Washington, D.C. Federal office building over the next 15 years, given that today's price of electricity is 6¢ per kWh, and the annual energy consumption is 8,000 kWh? What is the equivalent annual value?

4. What is the estimated present value of a reduction of 10,000 gallons/year in distillate fuel oil consumption for heating a Federal office building in Boston, given that the current price per gallon is $1.30, and the savings are expected to continue over the remaining life of the building, estimated at 50 years? What is the equivalent annual cost?

5. What is the DoE-projected average U.S. price per cubic foot of natural gas for commercial-type use in mid-1983?

6. What is the total present value cost over its useful life of purchasing, installing, operating, maintaining, and, finally, disposing of a heat pump for a house on a military base in Washington, D.C. given the following assumptions:

   - Initial purchase and installation cost = $1,500
   - Annual maintenance cost, constant $ = $350
   - Compressor replacement in year 8, constant $ = $400
   - Salvage value (net of disposal costs) at end of life = $250
   - Useful life = 15 years
   - Annual electricity costs, valued at the beginning of the study period = $800

Programmable Time Clock Problem

[Note: This is a hypothetical example intended only to illustrate the technique.]

Problem Statement: An energy-conserving retrofit is being considered for the Federal office and courthouse building in Houston, Texas (DoE Region 6). The remaining life of the building is expected to be 20 years or more.

At present, the building has a mechanical time clock that turns building HVAC equipment on and off. This clock runs all HVAC equipment during overtime hours. A programmable time clock could reduce after-hours equipment usage by turning on only needed HVAC equipment. It is estimated that the programmable clock would reduce by 80 percent the current after-hours electricity consumption of 323,220 kWh per annum.

The price of electricity to the agency is $0.0373 per kWh. The programmable clock would last for 20 years and cost $9,000 to purchase and install. There are no other sizable costs or salvage values associated with either clock.

Determine: Is the proposed time clock retrofit cost effective?

New Building Design Problem

[Note: This is a hypothetical example intended only to illustrate the technique.]

Problem Statement: An energy-conserving building design is being considered as an alternative to a conventional building design for a Federal office building in Madison, Wisconsin (DoE Region 5). The two designs are approximately equivalent in total assignable and auxiliary spaces and in functional performance with respect to the purpose of the building. Each has two underground levels for parking and seven office floors, plus a mechanical house. Each has a floor area of approximately 176,000 ft^2 (gross).

The two designs differ primarily in the envelope, building configuration, orientation, and lighting systems. The energy-conserving design is slightly elongated on the east-west axis for greater exposure of the south side to solar radiation. The window area of the energy-conserving design is 25 percent of the wall area and most of that is located on the south side; in the conventional building, it is 40 percent. More massive exterior surfaces are used and insulation is increased, reducing the wall U value from 0.16 to 0.06, and the roof U value from 0.15 to 0.06. Horizontal window fins reduce the summer cooling load of the energy-conserving design. The north wall of the first floor of the energy-conserving design is earth be-med. It is assumed that both designs will last at least 25 years, and, for lack of a good basis for projecting differences in their salvage values, they are both assumed to have no salvage value remaining at the end of the 25-year study period.

Following is a listing of the major relevant costs for each design:

	Energy-Conserving Design	Conventional Design
(a) Site acquisition costs: (To ensure adequate exposure of south-facing windows, an additional acquistion cost of $100,000 is necessary for the energy-conserving design. Other site costs are assumed to be identical for both designs, and hence are not shown.)	$100,000	
(b) Architectural and Engineering Design Fees and Construction Costs:	$9,780,000	$9,130,000
(c) Annual Energy Consumption:		
Natural Gas	$2,290 \times 10^6$Btu	$4,980 \times 10^6$Btu
Electricity	$3,866 \times 10^6$Btu	$7,277 \times 10^6$Btu

New Building Design Problem, Continued

	Energy-Conserving Design	Conventional Design
(d) DoE Energy Prices:		
Natural Gas	\$ 3.84/10^6Btu	\$ 3.84/10^6Btu
Electricity	15.67/10^6Btu	15.67/10^6Btu
(e) Nonfuel O&M Costs:		
Recurring Annual Cost:	\$70,000	\$90,000
Repairs to External Surfaces Every 10 Years:	\$60,000	\$100,000

Which design has the lowest life-cycle cost?

6 Problems: Solution

1. P = \$7,130
   A = \$1,739

2. P = \$10,590
   A = \$1,000

3. P = \$5,314
   A = \$583

4. P = \$231,010
   A = \$19,821

5. Mid-1983 = $\$0.004/ft^3 (1 + .0885)^2 = \$0.0047/ft^3$

6. LCC = \$10,954

Programmable Time Clock: Solution

Schedule A -- Electricity: (1) 323220kWh; (2) $0.0373/kWh; (3) $12056.11;

(4) 12.92; (5) $155765; Total $155765.

Schedule B -- 0

Schedule C -- 0

Schedule D -- 0

Schedule E -- (1) $155765; (2)-(6) 0; (7) $155765.

Schedule F -- (1) 64644kWh (323220 x 0.2 = 64644); (2) $0.0373/kWh;

(3) $2411.22; (4) 12.92; (5) $31153; Total $31153.

Schedule G -- (1) $9000; (2) 0.9 (1 - 0.1 = 0.9); (3) $8100; (4) 0;

(5) $8100.

Schedule H -- 0

Schedule I -- 0

Schedule J -- (1) $31153; (2) $8100; (3)-(6) 0; (7) $39253.

Schedule K -- (1) $155765; (2) $39253; (3) $116512.

Schedule L -- (1) (a) $124612; (b) 0; (c) $124612; (2) (a) $8100; (b)-(c) 0;

(d) $8100; (3) 15.38.

New Building Design Problem: Solution

Schedule A -- Electricity: (1) 3,866 x 10^6 Btu (7,277 x 10^6 Btu); (2) \$15.67/10^6 Btu; (3) \$60,580.22 (\$114,030.59); (4) 14.23; (5) \$862,057 (\$1,622,655).

Gas: (1) 2,290 x 10^6 Btu; (4,980 x 10^6 Btu); (2) \$3.84/10^6 Btu; (3) \$8,793.60 (\$19,123.20); (4) 18.68; (5) \$164,264 (\$357,221).

Totals: \$1,026,321 (\$1,979,876)

Schedule B -- (1) \$9,880,000 (\$9,130,000); (2) 0.9; (3) \$8,892,000 (\$8,217,000).

Schedule C -- (1) \$70,000 (\$90,000); (2) 11.65; (3) \$815,500 (\$1,048,500).

Schedule D -- For 10 years: (2) \$60,000 (\$100,000); (5) 0.51; (6) \$30,600 (\$51,000). For 20 years: (2) \$60,000 (\$100,000); (5) 0.26; (6) \$15,600 (\$26,000).

Totals: (6) 46,200 (\$77,000)

Schedule E -- (1) \$1,026,321 (\$1,979,876); (2) \$8,892,000 (\$8,217,000); (3) \$815,500 (\$1,048,500); (4) \$46,200 (\$77,000); (5)-(6), 0; (7) \$10,780,021 (\$11,322,376).

Section 12

Problem Set B

This section contains more comprehensive building investment problems, presented as follows:

(1) Water Conservation Problem

(2) Team Problem--Planning an Energy Conservation Package

(3) Computer Room Waste Heat Recovery Problem

Solutions to these problems are provided at the end of this section.

Water Conservation Problem

[Note: This is a hypothetical example intended only to illustrate the technique.]

Problem Statement: A Federal office and courthouse building is part of the Oklahoma City Federal Complex in Oklahoma City, Oklahoma. It is expected to be continued in use indefinitely. An energy-conserving retrofit has been proposed.

Data and Assumptions: Currently, water consumption of the 8 showers and 105 faucets in the building totals 28,056 gallons per month. It is estimated that by installing flow restricting showerheads and faucet aerators on these fixtures, water consumption would decrease by 30 percent. In addition, these devices would reduce the quantity of steam required for heating water, since less would be heated. It is estimated that steam consumption of the fixtures would be lowered from 60,583 to 42,408 pounds per year, and the maximum hourly consumption rate of 20.2 pounds per hour would be reduced to 14.2 pounds per hour.

The local water utility charges the agency $0.65 per 1000 gallons of consumption. The purchased steam (produced from natural gas) has two separate charge components: (1) $0.0049 per pound of consumption, and (2) a monthly charge of $0.09 per pound per hour for the maximum hourly consumption rate. The flow restricting showerheads would cost $7.00 each, and the faucet aerators $1.14 each. It is assumed that there are no other significant costs or salvage values associated with these devices. Both devices are expected to last for 5 years.

There is a limited sum of $10,000 that has been budgeted for the retrofit of the building. Other retrofit project opportunities are as follows:

(1) A group of small projects, R, S, T, and U, costing a total of $2,000 and saving a total of $10,000 in present value dollars.
(2) Project V, having a first cost of $1,600 and a total present value saving of $12,000.
(3) Project W, having a first cost of $10,000 and a total present value saving of $80,000.
(4) Project X, having a first cost of $2,000 and a total present value saving of $25,000.
(5) Project Y, having a first cost of $3,000 and a total present value saving of $36,000.
(6) Project Z, having a first cost of $1,000 and a total present value saving of $9,000.

(Note: Assume 10% adjustment factor to investment costs does not apply to projects R-Z.)

Determine: Is the proposed water conservation retrofit cost effective? Do you recommend that the water conservation project be included in the projects funded by the $10,000 budget?

Team Problem--Planning an Energy Conservation Package

[Note: This is a hypothetical example intended only to illustrate the technique.]

Problem Statement: Plan an energy conservation package for military base housing that will maximize net savings, given the following conditions and candidate retrofit projects. The housing is located in Washington, D.C. Its remaining life is expected to be 15 years. The agency has a limited budget of $2,000 to spend on each house.

Each house has been weatherstripped and caulked. It has R-11 insulation in the attic, as well as all the insulation that can be accommodated in the floors and walls without making major structural modifications. A jacket has been added to the domestic water heater, and thermal draperies have been added to the windows.

Each house is currently heated by an electric resistance system that is in good condition and could reasonably be expected to last over the remaining 15 year life of the house with only negligible maintenance and repair. The efficiency of the system is assumed to be 100 percent. The annual space heating load is 100 x 10^6Btu per house. The base now pays $16.89 per 10^6Btu ($0.06 per kWh) of electricity. The annual domestic hot water load is 22 x 10^6Btu per house. Hot water is currently supplied by an electric water heater that is expected to last over the remaining 15 year life of the house with only negligible maintenance and repair. The efficiency of the existing hot water system is assumed to be 100 percent.

The following options are being considered for retrofit to each house:

(A) Addition of a solar domestic water heater. The system that has been recommended as reliable and sufficiently durable to last the 15 years without major maintenance or repair costs $1,600, and is expected to meet 80 percent of the annual hot water load. No net salvage value is expected.

(B) Replacement of the existing electric resistance space heating system with a higher efficiency (1.8 COP) heat pump. The replacement of the existing system with the heat pump will cost $1,700. No net salvage value is expected from disposal of the existing system. The heat pump is expected to have about the same maintenance and repair costs and life expectancy as the existing system.

(C) Addition of attic insulation to raise the current resistance (R) level from R-11 to R-19. The insulation will cost $300 to purchase and install and is expected to reduce the energy consumption for space heating by 5 percent.

(D) Replacement of incandescent lighting with fluorescent lighting. The fluorescent lighting will cost $300 to purchase and install and is expected to reduce by 60 percent the 2000 kWh annual consumption rate of the existing lighting. Over the 15 year project life, the economic effects of the longer lives of the fluorescent tubes and their higher replacement costs are expected to be offsetting. There are assumed to be no salvage values associated with either the incandescent or fluorescent lighting.

Computer Room Waste Heat Recovery Problem

[Note: This is a hypothetical example intended only to illustrate the evaluation technique.]

Problem Statement: Would you recommend the following retrofit project for a Federal office building in Washington, D.C. (DoE Region 3)? The proposed project is to install a heat exchanger (with necessary piping and valves) for recovery of heat from waste condenser water from a computer room chiller for the purpose of preheating domestic hot water for the building.

Data and Assumptions:

(1) Condenser water at 95°F is currently delivered from the computer room water chiller to the cooling tower for dissipation of the thermal energy to the atmosphere.

(2) Purchased steam at $9.00 per thousand lbs (Mlb) is currently used to heat domestic hot water for the office building. The energy content of the steam is 1.05×10^6Btu/Mlb. The supplier of the steam uses coal to generate the steam with a plant efficiency of 65%.

(3) Domestic hot water consumption averages 1 gallon per person per day (GPD). The building is occupied 252 days per year and daily occupancy averages 3,000 people (P). The water intake temperature averages 60°F and the supply temperature is 120°F.

(4) Passing the 60°F domestic water supply through a heat exchanger through which the 95°F waste condenser water is routed will preheat it to 80°F.

(5) The installed cost of the heat exchanger (including all piping and insulation and values) is estimated at between $6,000 and $7,000, depending on potential problems that may be encountered in installation.

(6) Maintenance cost on the heat recovery system is estimated at $200 per year.

(7) A replacement cost of $500 for retubing the heat exchanger is expected at the end of 15 years.

(8) With proper maintenance and periodic replacements, the system is expected to last at least 25 years.

Note: Annual Energy Consumption (Mlbs. of steam) = [GPD x P x Dy/Yr x 8.34 lb/G x ΔT] ÷ 1.05×10^6Btu/Mlb.

Determine:

(A) Net present value savings.

(B) SIR for ranking this project relative to other projects.

(C) The break-even purchase and installation price of the heat exchanger.

Water Conservation Problem: Solution

Schedule A -- Steam from Gas: (1) 60583lb; (2) $0.0049/lb; (3) $296.86 (base), $21.82 (demand); (4) 5.18; (5) $1538 (base), $113 (demand); Total $1651

Schedule B -- 0

Schedule C -- (1) $218.84; (2) 4.10; (3) $897

Schedule D -- 0

Schedule E -- (1) $1651; (2) 0; (3) $897; (4)-(6) 0; (7) $2548

Schedule F -- (1) 42408lb; (2) $0.0049/lb; (3) $207.80 (base), $15.34 (demand); (4) 5.18; (5) $1076 (base), $79 (demand); (6) $1155

Schedule G -- (1) $175.70 [($7.00/showhd. x 8 show) + ($1.14/aerator x 105 faucets) = $175.70]; (2) 0.9; (3) $158; (4) 0; (5) $158

Schedule H -- (1) $153.19 [28056G/mo x 0.7 x 12mo x $0.65/1000G = $153.19; (2) 4.10; (3) $628

Schedule I -- 0

Schedule J -- (1) $1155; (2) $158; (3) $628; (4)-(6) 0; (7) $1941

Schedule K -- (1) $2548; (2) $1941; (3) $607

Schedule L -- (1) (a) $496; (b) -$269; (c) $765; (2) (a) $158; (b) 0; (c) 0; (d) $158; (3) 4.84

PROJECT SELECTION - LIMITED BUDGET

PROJECTS	SIR	RANKING NO BUDGET CONSTRAINT	FIRST COST ($)	NET SAVINGS ($)
Water-saving devices	4.84	(7)	176	607
R,S,T,U	5.0	(6)	2,000	8,000
V	7.5	(5)	1,600	10,400
W	8.0	(4)	10,000	70,000
X	12.5	(1)	2,000	23,000
Y	12.0	(2)	3,000	33,000
Z	9.0	(3)	1,000	8,000

OPTIONS WITHIN BUDGET:	Project W		All project except W
	First cost = $10,000 NS = $70,000	or	First cost = $9,776 NS = $83,007

Team Problem--Planning an Energy Conservation Package: Solution

Install Solar Domestic Water Heater:

Schedule A -- (1) 22mmBtu; (2) $16.89/mmBtu; (3) $371.58; (4) 11.07;

(5) $4113; Total $4113

Schedule B -- 0

Schedule C -- 0

Schedule D -- 0

Schedule E -- (1) $4113; (2)-(6) 0; (7) $4113

Schedule F -- (1) 4.4mmBtu; (2) $16.89/mmBtu; (3) $74.32; (4) 11.07;

(5) $823; Total $823

Schedule G -- (1) $1600; (2) 0.9 (1.0 - 0.1 = 0.9); (3) $1440; (4) 0;

(5) $1440

Schedule H -- 0

Schedule I -- 0

Schedule J -- (1) $823; (2) $1440; (3)-(6) 0; (7) $2263

Schedule K -- (1) $4113; (2) $2263; (3) $1850

Schedule L -- (1) (a) $3290; (b) 0; (c) $3290; (2) (a) $1440; (b)-(c) 0;

(d) $1440; (3) 2.28

Install Heat Pump:

Schedule A -- (1) 100mmBtu; (2) $16.89/mmBtu; (3) $1689; (4) 11.07;

(5) $18697

Schedule B -- 0

Schedule C -- 0

Schedule D -- 0

Schedule E -- (1) $18697; (2)-(6) 0; (7) $18697

Schedule F -- (1) 55.56mmBtu; (2) $16.89/mmBtu; (3) $938.41; (4) 11.07;

(5) $10388; Total $10388

Schedule G -- (1) $1700; (2) 0.9 (1.0 - 0.1 = 0.9); (3) $1530; (4) 0;

(5) $1530

Schedule H -- 0

Schedule I -- 0

Schedule J -- (1) $10388; (2) $1530; (3)-(6) 0; (7) $11918

Schedule K -- (1) $18697; (2) $11918; (3) $6779

Schedule L -- (1) (a) $8309; (b) 0; (c) $8309; (2) (a) $1530; (b)-(c) 0;

(d) $1530; (3) 5.43

Add R-11 to R-19 Insulation:

Schedule A -- (1) 100mmBtu; [55.56mmBtu]; (2) $16.89/mmBtu; (3) $1689 [$938.41]; (4) 11.07; (5) $18697 [$10388]; Total $18697 [$10388]

Schedule B -- 0

Schedule C -- 0

Schedule D -- 0

Schedule E -- (1) $18697 [$10388]; (2)-(6) 0; (3) $18697 [$10388]

Schedule F -- (1) 95mmBtu [52.78mmBtu]; (2) $16.89/mmBtu; (3) $1604.55 [$891.45]; (4) 11.07; (5) $17762 [$9868]

Schedule G -- (1) $300; (2) 0.9; (3) $270; (4) 0; (5) $270

Schedule H -- 0

Schedule I -- 0

Schedule J -- (1) $17762 [$9868]; (2) $270; (3)-(6) 0; (7) $18032 [$10138]

Schedule K -- (1) $18697 [$10388]; (2) $18032 [$10138]; (3) $665 [$250]

Schedule L -- (1) (a) $935 [$520]; (b) 0; (c) $935 [$520]; (2) (a) $270; (b)-(c) 0; (d) $270; (3) 3.46 [1.93]

Install Lighting:

Schedule A -- (1) 2000kWh; (2) $0.06/kWh; (3) $120; (4) 11.07; (5) $1328; Total $1328

Schedule B -- 0

Schedule C -- 0

Schedule D -- 0

Schedule E -- (1) $1328; (2)-(6) 0; (7) $1328

Schedule F -- (1) 800kWh; (2) $0.06/kWh; (3) $48; (4) 11.07; (5) $531; Total $531

Schedule G -- (1) $300; (2) 0.9; (3) $270; (4) 0; (5) $270

Schedule H -- 0

Schedule I -- 0

Schedule J -- (1) $531; (2) $270; (3)-(6) 0; (7) $801

Schedule K -- (1) $1328; (2) $801; (3) $527

Schedule L -- (1) (a) $797; (b) 0; (c) $797; (2) (a) $270; (b) 0; (c) 0; (d) $270; (3) 2.95

PROJECT SELECTION

PROJECT	PROJECT COST ($)	SIR	NET SAVINGS ($)	SELECTION
Heat pump	1700	5.43	6,779	X
Insulation without HP	300	3.46	665	
Lighting	300	2.95	527	X
Solar water heater	1600	2.28	1850	
Insulation with HP	300	1.93	250	

Computer Room Waste Heat Recovery Problem: Solution

Schedule A -- steam: (1) 360.3 Mlb (1GPD x 3000P x 252Dy/Yr x 8.341b/G x (120 - 60)) ÷ 1.05 mmBtu/Mlb = 360.3Mlb; (2) $9.00/Mlb; (3) $3243; (4) 15.93; (5) $51654

Schedule B -- 0

Schedule C -- 0

Schedule D -- 0

Schedule E -- (1) $51654; (2)-(6) 0; (7) $51654

Schedule F -- (1) 240.2Mlb (1GPD x 3000P x 252Dy/Yr x 8.341b/G x (120 - 80)) ÷ 1.05mmBtu/Mlb = 240.2Mlb); (2) $9.00/Mlb; (3) $2162; (4) 15.93; (5) $34436; Total $34436

Schedule G -- (1) $6000 - $7000; (2) 0.9 (1 - 0.1 = 0.9); (3) $5400 - $6300; (4) 0; (5) $5400 - $6300

Schedule H -- (1) $200; (2) 11.65; (3) $2330

Schedule I -- (1) 15; (2) 0; (3) $500; (4) 0; (5) .36; (6) 0 (7) $180; (8) 0; Totals (6) 0, (7) $180; (8) 0

Schedule J -- (1) $34436; (2) $5400 - $6300; (3) $2330; (4) 0; (5) $180; (6) 0; (7) $42346 - $43246

Schedule K -- (1) $51654; (2) $42346 - $43246; (3) $8408 - $9308

Schedule L -- (1) (a) $17218; (b) -$2330; (c) $14888; (2) (a) $5400 - $6300; (b) $180; (c) 0; (d) $5580 - $6480; (3) 2.30 - 2.67

Break-Even (with adj. factor): .9P&I(BE) = $17218 - $2330 - $180 = $14708/.9 = $16342, where P&I(BE) = break-even purchase and installation cost.

Section 13

Problem Set C

This section contains problems related to the treatment of uncertainty in project analysis, presented as follows:

(1) Sensitivity Analysis Problem: Insulation

(2) Problem in Probability Analysis: Heat Pump Versus Solar Energy System

Solutions to these problems are provided at the end of this section.

Sensitivity Analysis Problem: Insulation

[Note: This is a hypothetical example intended only to illustrate the technique.]

Problem Description: Assume that you, as a homeowner, wish to insulate your attic, which is currently uninsulated, to reduce your electricity cost. The house is heated by an electric resistance system and the current price of electricity is \$.057/kWh (\$16.77/10^6Btu). You expect to remain in the house another 25 years. Your best alternative use of the money you have available to spend on insulating the house is for a tax-free bond paying 10% compounded annually. Current inflation is about 3% per year. The house is located in Washington, D.C.

Using the Means Building Construction Cost Data Guide as a rough approximation of costs,* you find the following cost data for this area for fiberglass batts:

	Material Cost ($\$/ft^2$)	Labor ($\$/ft^2$)	Overhead and Profit (Multiplier)
R-11	.14	.06	1.25
R-19	.24	.07	1.23
R-30	.40	.08	1.17
R-38	.55	.09	1.15

In the past you have occasionally seen a 50% sale on installed insulation. However, you haven't seen any sales recently and do not know if the lower price will be available.

Further, you have noted a recent upswing in the local building industry which may have driven labor rates sharply higher--as much as double those reported by Means.

The area to be insulated is 1,200 ft^2. You are basing your energy savings on DoE-projected price increases in energy, based on a recent research report by the National Bureau of Standards which estimated the annual savings from attic insulation for a house similar to yours as follows:

	Change in Annual Heating Requirments (10^6Btu)
0-R-11	12.913
0-R-19	14.987
0-R-30	16.315
0-R-38	16.833

Determine: How sensitive is the optimal level of attic insulation to these potential variations in costs.

*R.S. Means assumes large job sizes so these costs will tend to be lower than what the homeowner would face.

Problem in Probability Analysis: Heat Pump Versus Solar Energy System

[Note: This is a hypothetical problem intended only to illustrate the technique.]

A heat pump and a solar energy system are two alternatives being considered for retrofit to a number of similar Federal facilities. If the solar energy system is installed, the existing heating system will be used as an auxiliary system. The heat pump requires no auxiliary system. A major area of concern is whether or not the existing system will provide reliable auxiliary service without major overhaul costs. Expert judgment is that there is about a 30 percent chance that the existing system in a given facility will be found to require major overhaul in order to provide auxiliary service to the solar energy system, and a 70 percent chance that no major repairs or modifications will be needed. If no major overhaul is needed, the combined life-cycle cost of the solar/auxiliary system is estimated at $20,000; and if major overhaul is needed, at $35,000. The life-cycle cost of the heat pump is estimated at $25,000. Which system do you recommend on the basis of minimizing the expected value of the life-cycle cost?

Sensitivity Analysis Problem: Solution

Insulation Level	Annual Heating Required (10^6 Btu)	Total PV Savings $	Total PV Costs Low	Total PV Costs Med.	Total PV Costs High	Net Savings Low Cost	Net Savings Med. Cost	Net Savings High Cost
0-R11	12.913	3,105	150	300	390	2,955	2,805	2,715
0-R19	14.987	3,604	229	458	561	3,375	3,146	3,043
0-R30	16.315	3,923	337	674	786	3,586	3,249	3,137
0-R38	16.833	4,048	442	883	1,007	3,606	3,165	3,041

Probability Analysis Problem: Solution

EV (Heat Pump) = \$25,000

EV (Solar/Auxiliary) = (\$20,000) • (.7) + (\$35,000) • (.3) = \$24,500

There is very little difference in the expected value of the outcomes; but the solar/auxiliary system is expected to have a slightly smaller life-cycle cost and could be recommended on that basis.

Section 14

Problem Set D

This section contains problems whose solutions utilize other analysis techniques such as break-even analysis and replacement methodology. The problems are presented as follows:

(1) Team Problem--Break-Even Orders for a Computerized Procurement System

(2) Team Problem--Determining Optimal Retirement of Equipment

Solutions to these problems are provided at the end of this section.

Team Problem--Break-Even Orders for a Computerized Procurement System

[Note: This hypothetical problem is intended only to illustrate the technique.]

Problem Statement:

A Federal agency procurement office is considering the purchase of a new computerized system that is expected to cut average labor time per order in half. The number of orders has been identified as a key determinant of the cost effectiveness of the system, and management wishes to make the decision based on cost effectiveness.

Past trends in procurement orders have been analyzed, and a projection has been made of future orders in terms of lower and upper boundary estimates. Over the next three years, the average projected low estimate is 500 orders per year and the average high is 800. Other data and assumptions are given below:

Data and Assumptions:

System purchase and installation cost = \$45,000

Annual maintenance cost = \$2,000
(Fixed by contract in constant dollars)

Service charge per order = \$1.00
(Fixed by contract in constant dollars)

System life = 10 years

Salvage = 0

Labor savings per order = \$12.00
(Constant dollars)

To Do:

Based on the data and assumptions, perform a break-even analysis of the annual procurement orders and, on this basis, advise management on the decision.

[Note: Assume the project is not regarded as an energy conservation project.]

Team Problem--Determining Optimal Retirement of Equipment

[Note: This hypothetical example is intended only to illustrate the technique.]

Problem Statement: The existing motor-generator sets which power passenger and freight elevators in a Federal building complex consume 2 million kWh's of electricity per year. At the time of the analysis (early 1983), electricity costs $0.06/kWh, and the price is projected to increase over the next 5 years at an annual compound rate 5 percent faster than general price inflation and thereafter at a rate 1 percent faster than the general inflation rate.

With an extensive overhaul and modifications costing $50,000, it is estimated that annual power consumption could be reduced by 15 percent and equipment life extended to as long as 25 years. Without the overhaul, the equipment is expected to last another 5 years, at which time overhaul will no longer be feasible.

New elevator power equipment is available at a purchase and installation cost of $400,000. It will cost $20,000 to remove and dispose of the old equipment and to prepare the machine rooms to receive the new equipment. There is no resale or reuse market for this kind of equipment when it is removed from service. The new equipment is expected to be 25 percent more energy efficient than the existing equipment without the overhaul. The new equipment is expected to last for the duration of the building life which is estimated to be indefinite.

No appreciable difference is estimated in maintenance and repair costs of the new and existing system, whether overhauled or not. The new equipment is expected to continue to be "state-of-the-art" for the foreseeable future, and its constant dollar costs are expected to remain the same over time.

Determine:

(1) Decision alternatives to be considered.

(2) The estimated least-cost alternative.

(3) The net savings estimated to be derived from making the cost-effective decision.

BREAK-EVEN: LABOR-MACHINE DECISION

SOLUTION - Find break-even no. of orders and compare with projected no. of orders

PV costs = PV savings

\$45,000 + (\$2,000 × UPW_{10}) + (\$1.00 × no.orders × UPW_{10}) =
\$12.00 × no. orders × UPW_{10}

\$45,000 + (\$2,000 × 6.145) + (\$1.00 × no. orders × 6.145) =
\$12.00 × no. orders × 6.145

\$45,000 + \$12,290 + 6.145 no. orders = 73.74 no. orders

67.60 no. orders = 57,290

Break-even no. orders = 847.49 annually

Team Problem -- Determining Optimal Retirement of Equipment: Solution

KEEP EXISTING EQUIPMENT "AS IS" FOR 5 YRS, THEN REPLACE

ENERGY COSTS, YRS. 1-5 | **NEW EQUIP. COST, END OF YR. 5**

$$PV = [2{,}000{,}000\text{kWh} \times \$0.06/\text{kWh} \times UPW^*_{5\,yr,\,7\%,\,5\%}] + [(\$400{,}000 + 20{,}000) \times SPW_{5\,yr,\,7\%}]$$

ENERGY COSTS, YRS. 6-25

$$+ [(1-0.25) \times 2{,}000{,}000 \times \$0.06 \times SCA_{5\,yr,\,5\%} \times UPW^*_{20\,yr,\,7\%,\,1\%} \times SPW_{5\,yr,\,7\%}]$$

$$= [2{,}000{,}000 \times \$0.06 \times 4.73] + [\$420{,}000 \times 0.71] + [0.75 \times 2{,}000{,}000 \times \$0.06 \times 1.28 \times 11.53 \times 0.71]$$

$$= \$1{,}808{,}862$$

RETIRE EQUIPMENT IMMEDIATELY

NEW EQUIPMENT **ENERGY COSTS, YRS. 1-25**

$$PV = [\$400{,}000 + 20{,}000] + [(1-0.25) \times 2{,}000{,}000 \times \$0.06 \times [UPW^*_{5\ yr,\ 7\%,\ 5\%} + (SCA_{5\ yr,\ 5\%} \times UPW^*_{20\ yr,\ 7\%,\ 1\%} \times SPW_{5\ yr,\ 7\%})]]$$

$$= \$420{,}000 + [0.75 \times 2{,}000{,}000 \times \$0.06 \times [4.73 + (1.28 \times 11.53 \times 0.71)]]$$

$$= \$1{,}788{,}762$$

OVERHAUL EXISTING EQUIPMENT

OVERHAUL COST	ENERGY COSTS, YRS. 1-25

$$PV = [\$50{,}000] + [(1\text{-}0.15) \times 2{,}000{,}000 \times \$0.06 \times [UPW^{*}_{5\ yr,\ 7\%,\ 5\%} + (SCA_{5\ yr,\ 5\%} \times UPW^{*}_{20\ yr,\ 7\%,\ 1\%} \times SPW_{5\ yr,\ 7\%})]]$$

$$= \$50{,}000 + [0.85 \times 2{,}000{,}000 \times \$0.06 \times [4.73 + (1.28 \times 11.53 \times 0.71)]]$$

$$= \$1{,}601{,}263$$

COST-EFFECTIVE DECISION

- Overhaul existing equipment

- Net savings:
  - $207,599 Relative to keeping equipment "as is" for 5 yrs, then replacing
  - $187,499 Relative to retiring existing equipment immediately

TAB 15

PROBLEM SET 15

This tab contains a sample economic evaluation report.

Problem Set E

Team Critique of an Economic Evaluation Report

Critique this report as a team. Identify errors in problem formulation, assumptions, analysis, and recommendations. Describe the nature of the errors and how you would have avoided them. Select a representative of your team to present to the class your version of an improved report.

Energy Conservation Feasibility Study

Federal Building I
Washington, D.C.

Submitted by
XYZ Associates
Contractors Park, USA

[Note: This is purely a hypothetical examp[illegible]ended only as an instructional aid for illustrating important elements of an economic evaluation report.]

1. Objective and Scope

This report analyzes six alternatives for reducing utility costs in Federal Building I, an existing office building in Washington, D.C. The report provides GSA decision makers with economic guidance as to which conservation retrofits to select in light of the GSA objective of maximizing net savings from energy conservation subject to budgeting constraints.

2. Alternatives

The six alternatives are time clocks for lighting control, additional roof insulation, storm windows on the North side, flow restrictors for saving hot water in restrooms, use of cool night air to precool the building during the summer, and insulated window drapes. Other alternatives were considered, but they were rejected because their savings were difficult to calculate.

3. Assumptions and Data

A study period of 25 years is used for energy retrofits, and a study period of 20 years is used for the flow restrictors.

A real discount rate of 10% is used for evaluating the roof insulation and time clocks, and a real discount rate of 13% is used for the rest of the retrofits.

All future costs that are discounted to present values are stated in current dollars to account for inflation.

The report evaluates retrofits for the 1984 budget year. Since agency funding for 1984 is not yet determined, three budget levels covering the range that might be expected are assumed as follows: $92,000; $145,000; and $400,000. An economically efficient set of retrofit projects is selected for each of the three budget levels.

Occupant satisfaction with the building in terms of thermal comfort, lighting levels, and water supply are assumed to be unaffected by the proposed retrofits.

4. Analysis

The conservation retrofits are arranged in descending order of their cost effectiveness. Since the objective is to maximize net savings from conservation retrofits, column 4 (net dollar savings) determines the ranking of the six projects.

All projects except using cool night air to precool buildings in the summer are estimated to be cost effective in the sense that the SIR is greater than 1.0 and the payback is less than four years.

To maximize net savings under each of three budget scenarios, each project should be selected in the order given by column 5 until net savings become zero or negative, or until the budget is exhausted.

Table 1. Summary of Conservation Retrofits

Retrofit	Total Life-Cycle Cost Savings [a] $ (1)	First Cost $ (2)	SIR (3)=(1)÷(2)	Net Savings $ (4)=(1)-(2)	Economic Priority (5)
Storm Windows on North Side	276,000	90,500	3.0	185,000	1
Time Clocks for Lighting Control	226,000	53,400	4.2	172,600	2
Flow Restrictors in Restrooms	55,000	3,000	18.3	52,000	3
Roof Insulation	53,000	2,600	20.4	50,400	4
Insulated Window Drapes	206,300	195,500	1.1	10,800	5
Cool Night Air to Precool Building in Summer	130,000	140,000	0.9	-10,000	6

[a] The data and calculations that underly the cost and savings figures in this table are available from a research assistant at XYZ Associates.

5. Recommendations

For a budget of $92,000, storm windows on the North side of the building should be installed. Storm windows yield the greatest net benefits. The $1,500 remaining is insufficient to undertake any of the other projects.

For a budget of $145,000, both the storm windows and the time clocks should be installed. The $1,100 remaining is insufficient to undertake any other project.

For a budget of $400,000, all of the projects except using cool night air to precool the building in summer should be selected. Having a budget larger than the cost of all available alternatives is equivalent to having no budget constraint. Therefore any project with a relatively large SIR should be undertaken. Using cool night air is rejected because its SIR is lower than any of the other retrofits. For this reason it would not be acceptable regardless of the budget size.

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Rosalie T. Ruegg

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10. SUPPLEMENTARY NOTES

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

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

This workbook has been prepared for participants in the seminar, "Economic Evaluation of Building Design, Construction, Operation and Maintenance." It has two main functions: (1) to provide basic resource materials, references, and introductions to methods employed in the seminar and (2) to provide instructional problems for solution by the participants. Specifically, it contains brief discussions of key elements in performing economic evaluations: discounting, escalation, establishing a study period, project selection techniques, and treatment of uncertainty; explanations of supporting analysis techniques: break-even analysis and replacement theory; and problems, worksheets, and solutions. Cross references are given to related sections of a reference manual (NBS Handbook 135) and to case studies which illustrate the topics. The objectives of the seminar are to provide participants with a working knowledge of economic evaluation procedures for making building decisions, and to improve their decision-making abilities related to cost management and to the design and selection of buildings and building systems. The seminar has been developed for building design engineers and architects, project planning and programming staff, managers of building programs, procurement officers and contract coordinators, building constiuction estimators, and building analysts.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

cost effectiveness; economic evaluations; energy conservation; life-cycle costing; public buildings; solar energy.

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