BUREAU OF RECLAMATION

FACILITIES INSTRUCTIONS, STANDARDS, & TECHNIQUES

Volume 4 - 3

ECONOMIC ANALYSIS OF

MAINTENANCE PROBLEMS

September 1992

FOREWORD

Economic analysis is a systematic and well-defined study of alternatives. It is a concept, a way of thought-life, that:

- **!** Analyzes available resources
- **!** Identifies alternative ways of handling a problem
- **!** Compares results of alternative solutions
- **!** Recommends a solution based on well-defined data

Maintenance managers are well-advised to learn when and how to use economic analysis to guide their thoughts and verify their recommendations.

CONTENTS

LIST OF TABLES

1. INTRODUCTION AND PURPOSE

1.1. Maintenance can be expensive, particularly around powerplants and switchyards where valuable equipment is located. It is worthwhile to make an economic analysis of some maintenance programs, especially those that: run into large amounts of money (over $50,000, for example); extend over several years time; and where there are alternatives to consider to gain the desired results.

1.2. Economic analysis should *not be used* in situations where it is expected to:

- Produce results more valid than input data (garbage in, garbage out)
- Make final decisions
- Be applied with exact precision
- Provide relevant solutions to irrelevant problems
- Predict political, social, and other non-economic impacts
- Substitute for sound judgment, management, or control

A well-prepared economic analysis requires considerable though, research, and effort. Do *not make* an economic analysis when:

- The analytical effort is not worth the benefits
- Legislative directives or management decisions govern
- Other studies have already been made (usually by another name)

1.3. This bulletin is designed to show maintenance managers, by example, how to make an economic analysis of alternate ways to accomplish maintenance, thus giving them key information to arrive at the best decisions. Readers are shown how to analyze typical maintenance situations by using "discount factors" to determine the "present value" of benefits and costs, a very powerful tool to determine the value of future payments. However, economic analysis is but one of many factors that maintenance managers must consider; other Items such as Reclamation policies and social and environmental impacts may influence the decision more. Remember the advice in paragraph 1.2.; the economic analysis is no substitute for sound Judgment, management, or control. Although other factors may override economic considerations, maintenance managers should be familiar with, and frequently use, economic analysis to help guide their Judgments. This bulletin is for them.

2. THE THREE BASIC STEPS OF ANALYSIS

2.1. Economic analysis of a problem Involves three basic steps: (1) examine all alternatives; (2) determine costs and benefits of each alternative; and (3) compare costs and benefits of the alternatives.

2.2. *Examine all alternatives.*- For example, the alternatives of performing maintenance on power circuit breakers include: (1) perform periodic routine maintenance and major overhauls by force account labor, (b) perform periodic routine maintenance by force account labor but contract for performance of major overhauls, and (c) lengthen intervals between periodic maintenance to the point that occasional repairs are required and depend primarily on major overhauls every 5th (or 10th) year, etc. The list is limited only by one's Ingenuity and judgment of prudent actions. Consideration of alternatives usually involves one or more of the following:

- To do maintenance or to do nothing and accept occasional breakdowns
- To repair or replace damaged equipment
- To buy or lease special services or equipment such as communication circuits, computers, and test/inspection services
- To do manually or by machine (is the program labor intensive or capital intensive?)

- To manufacture equipment (spare parts, test sets, etc.) in-house or to buy from commercial sources
- To contract for services or to direct-hire required personnel
- To centralize or decentralize operations and/or maintenance crews and facilities (stores, warehouses, etc.)

Examples of the broad range of applications Include analysis of a turbine runner replacement or a generator rewind. As a maintenance manager, analyze your own facilities and programs with the thought of improving productivity, safety, and reliability. Stretch your thinking beyond the conventional, accepted norms; seek new solutions. Chances are the programs you Inherited are running on their own Inertia. Compare your existing programs with non-Reclamation programs In your area. Look at the old and keep what is good - what still makes sense - then evaluate alternatives for needed new programs.

2.3. *Determine costs and benefits.*- Set up a "discounting table" showing costs and/or benefits and their present values (P) for each year of the proposed program in the following format:

Once you understand this format and the examples given later on, you will be in a position to make rational economic decisions on an amazing variety of matters. The discounting table is the heart of the economic analysis, and, when properly applies, becomes a powerful tool. Now consider costs and benefits.

2.3.1. Costs typically Include such items as:

- Land
- Labor
- Material
- Leasing charges
- Contractor services
- Research and development
- Planning, design, and construction
- O&M expenses

The determination of costs is basic to economic analysis; it provides the decision maker with the economic facts that are available, so the economic sot of a decision is known before the program is started. Failure to determine economic costs is perhaps the greatest single cause of program failures. Cost information requires proper documentation to provide a trail for validation of the analysis. In giving cost data, four principles apply:

- State all assumptions
- State all sources
- Use full disclosure of all elements of the study
- Be consistent in the analysis

2.3.2. Benefits typically include such items as:

- Performance (productivity, safety, reliability)
- Output (capacity, volume, plant factor)

Program year	Discount factor	Alternative A		Alternative B	
		Costs (P)	Benefits (p)	Costs (P)	Benefits (p)
1 **2** **3** **4** **etc.**					

- Results (program accomplishment, Income, repayment)

- Reduced costs (must be real, not transferred elsewhere)

Anticipated benefits are, of course, the reasons any activity is undertaken in the first place. It is easy, and often dangerous, to become overly optimistic on benefits. Like costs, benefits are basic to economic analysis. They provide the decision maker with the economic facts available.

2.4. *Compare costs and benefits.*- It was great to be able to send men to the moon, but was it worth it? Such a difficult question defies economic answers since many noneconomic factors (such as political and social) are involved. Economic answers too many difficult questions can, however, be obtained by comparing costs and benefits. This can be done by using a discounting table similar to that shown in section 2.3, comparing the total present values (P) of costs and benefits for each alternative considered. To select the best alternative, use these rules:

- If benefits are equal, choose the least costly alternative.

- If costs are equal, choose the most productive alternative.

- If costs are unequal and benefits are unequal, use the alternative with the highest benefit/cost ratio.

3. THE TIME VALUE OF MONEY

3.1. Present value formula.- The following basic economic formula, relating time to money, defines the present value of money that will be spent in the future. This formula will be used in practically all of our economic comparisons.

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

where:

P = Present value of F dollars to be spent in a future year

F = Future dollars to be spent in year N
N = Number of years, after start of the study, that F dollars will be spent

I = Interest rate per year, expressed in decimal form

Table A shows present values calculated from this formula for a wide range of years and Interest rates. Using this formula, wherein the value of F is assumed to be $1, it is a simple matter to use a packet calculator to quickly develop your own table of present values for any interest rate. This present value formula provides the foundation for the basic economic principle:

- To enhance economic feasibility, attempt to delay payment of costs and accelerate accrual of benefits.

Using table A, solve the following "present value" problem:

- *Problem.*- You will need a supply of make-up insulating oil for transformers in about 8 years. You can buy insulating oil today for $50 a barrel. You guess that in 8 years, the same oil will cost $100 a barrel. If the annual interest rate is 10 percent, should you buy now or wait?.

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

$= 100/(1 + 0.10)^8$

= $46.65 per barrel

• *Solution.*-

Since the present value of the cost to buy oil in the future is lower than today's cost ($46.65 vs. $50 per barrel), you should not buy the oil today. In this example, we have assumed zero storage costs, which, if included, would have reinforced our decision not to buy today.

Table A. - *Present value of $1*

Spent Years hence (n)	*4% (0.04)*	*6% (0.06)*	*7% (0.07)*	*8% (0.08)*	*9% (0.09)*	*10% (0.10)*	*12% (0.12)(1)*
1	0.962	0.943	0.935	0.926	0.917	0.909	0.893
2	.925	.890	.873	.857	.842	.826	.797
3	.889	.IMO	.816	.794	.772	.751	.712
4	.855	.792	.763	.735	.708	.683	.636
5	.822	.747	.713	.681	.650	.621	.567
6	.790	.705	.666	.630	.596	.564	.507
7	.760	.665	.623	.583	.547	.513	.452
8	.731	.627	.582	.540	.502	.467	.404
9	.703	.592	.544	.500	.460	.424	.361
10	.676	.558	.508	.463	.422	.386	.322
11	.650	.527	.475	.429	.386	.350	.287
12	.625	.497	.444	.397	.356	.319	.257
13	.601	.409	.415	.368	.326	.290	.229
14	.577	.442	.388	.340	.299	.263	.205
15	.555	.417	.362	.315	.275	.239	.183
16	.534	.394	.339	.292	.252	.218	.163
17	.513	.371	.317	.270	.231	.198	.146
18	.404	.350	.296	.250	.212	.180	.130
19	.475	.331	.277	.232	.194	.164	.116
20	.456	.312	.258	.215	.178	.149	.104
21	.439	.294	.242	.199	.164	.135	.093
22	.422	.278	.226	.184	.150	.123	.083
23	.406	.262	.211	.170	.138	.112	.074
24	.390	.247	.197	.158	.126	.102	.066
25	.375	.233	.184	.146	.116	.092	.059
26	.361	.220	.172	.135	.106	.084	.053
27	.347	.207	.161	.125	.098	.076	.047
28	.333	.196	.150	.116	.090	.069	.042
29	.321	.185	.141	.107	.082	.063	.037
30	.308	.174	.131	.099	.075	.057	.033
40	.208	.097	.067	.046	.032	.022	.011
50	.141	.054	.034	.021	.013	.009	.003

The interest rate assumed is a critical item in the analysis. How does a maintenance manager decide what value to use? Long-term treasury bond yields are often used (see the example in part 5.1.), but we suggest you contact the Operation and Maintenance Engineering Branch, D-5850, Denver Office, for the proper rate for your problem.

3.2. *Sunk costs.*- Funds that have been spent are called "sunk costs." In economic analysis, always disregard sunk costs (except possibly to learn and moan) as they are now financially irrelevant. Economic analysis is for the purpose of examining expenditure of funds for future alternatives. Therefore, when a project is being built, an economic analysis that is performed in successive years during construction would show declining project costs, since funds already spent for construction are "sunk" and are no longer evaluated. If the benefits of such a project remain constant, or increase, the B/C (benefit/cost) ratio would increase for each new year in which the economic analysis is performed. With zero base budgeting concepts, economic analyses are often performed each year for a particular project, and if the project develops as expected, the successive analyses show increasing B/C ratios.

An example of a maintenance problem involving sunk costs is:

- *Problem.*- $1,000,000 have been spent on procurement and installation of airblast power circuit breakers. After 3 years of service, it has been found that the breakers are totally unreliable and will have to be replaced. The salvage value of the breakers for scrap metal is $10,000 net, Including removal costs. The cost of suitable new oil breakers is $1,500,000; should they be purchased?

- *Solution.*- The only relevant costs for economic analysis are: $1,500,00 (new breakers) - $10,000 (salvage) = $1,490,000 (net). The decision to spend a net of $1,490,000 for new breakers is independent of the $1,000,000 sunk cost.

4. ECONOMIC LIFE AND TERMINAL VALUE

An economic analysis extending over several years must recognize that equipment wears out and must be replaced. Usually it is not obvious what equipment life to assume, and we must rely on what experience has shown from operating similar equipment. Reclamation engineers have made detailed studies of equipment operating histories and have been able to establish statistical "service life" values for a wide variety of equipment and structures. A summary of these studies may be found in "Replacements-Units, Service Lives, Factors," Bureau of Reclamation, pages III-1 through III-11, May, 1989.

4.1. *Economic life.*- The service life, or economic life, of a class of equipment is the time in which savings (benefits) gained through using the equipment accrue to the organization. There are three ways to determine whether equipment has reached the end of its useful service life:

- Physical life - Determined to be over when the machine is no longer repairable

- Technological life - Determined to be over when the machine is made obsolete by availability of improved models.

- Product life - Determined to be over when there is limited production of an item, and the life ends with production of the last unit.

In evaluating these three methods, the shortest life from among the three should be used in the economic analysis.

4.2. *Terminal value.*- The selvage value, or terminal value, of equipment is determined, at the end of the equipment life, to be the sale value minus the cost of disposal. Terminal values are usually determined by making straight-line or percentage projections of equipment resale data. The most familiar source of terminal value data is the "Blue Book" used by automotive dealers in determining used car trade-in allowances for new car purchases. The terminal

value is used in an economic study as a "benefit" which accrues to the organization in the study year that it is salvaged. When in doubt, assume a zero salvage value at the end of the service life. Salvage value, when used, is discounted for the appropriate future year in order to determine its real economic benefit. Example:

- *Problem.*- An office computer has been purchased and installed for $5,000,000. Its terminal value 8 years later is estimated to be $50,000. What economic benefit does this value have? Assume an 8-percent interest rate.

- *Solution.*- The present worth of the computer salvage value is:

$$P = \frac{\$50{,}000}{(1+0.08)^8}$$

$$= \$27{,}013$$

5. EXAMPLES AND SOLUTIONS OF MAINTENANCE PROBLEMS

We will now make economic analyses of actual problems which are typical of those which are faced by Reclamation maintenance managers. Only the names are fictitious. Complete solutions are shown to illustrate the basic concepts discussed above.

5.1. *Replacement of the telephone cord board at Glen Echo Powerplant.-*

- *Problem.*- The maintenance manager is considering replacing the existing leased Type 555 cord board at Glen Echo Powerplant. This unit is old, obsolete, and cumbersome to operate. Also, the local telephone company has stated that the Type 555 is no longer in production and maintenance is difficult due to lack of parts. Clearly, the useful life of this equipment is over. The manager intends to replace it with a modern 40-line PABS switchboard and has asked for price quotations both from the telephone company and a private equipment supplier. The manager must now prepare a cost comparison, using rules defined in Treasury Department Circular A-76, to determine which of the following alternatives will produce the greatest savings to the Government: Alternative 1 - Lease the new PABS from the telephone company; or Alternative 2 - Reclamation purchase, Install, and maintain the equipment.

- *Solution.- Alternative* 1 - Leased service option from the telephone company. The company offers leased service under the following conditions.

  Tier A, full rent. - Five-year period $650 monthly recurring charge.

  Tier B, reduced rent.- After 5 years, the rent will reduce to $250 per month until terminated by Reclamation. On termination, there will be a one-time charge of $1,000 to remove the company's equipment.

  Main station charge. - $2.20 per main station per month. Maximum of 40 stations at $2.20 each = $88 monthly recurring charge for the duration of the lease.

  Contract administration charge.- $620 annual recurring charge.

  Installation charge.- One-time nonrecurring charge: $2,000.

Summary of costs by year- Alternative 1. -

Year 1:2,000 + 12 x (650 + 88) + 620
= $11,476

Years 2, 3, 4, 5:12(650 + 88) + 620
= $9,476

Year 6 to termination year: 12(250 + 88)
+ 620 = $4,676

Termination year: 1,000 + 12(250 + 88)
+ 620 = $5,676

Alternatives 1 and 2 will be designed to provide identical service; hence the benefits are assumed to be equal.

Table B. - *Discounting table for telephone cord board problem*

Year	Discount factor (8.91%)	Alternative 1 Cost	Alternative 1 (P)	Alternative 2 Cost	Alternative 2 (P)
1	0.981	$11,476	410,535	$20,465	$18,787
2	.843	9,476	7,988	1,500	1,264
3	.774	9,476	7,334	1,500	1,161
4	.711	9,476	6,737	1,500	1,066
5	.653	9,476	6,188	1,500	980
6	.599	4,676	2,801	1,044	625
7	.550	4,676	2,572	1,044	574
8	.505	4,676	2,361	1,044	527
9	.464	4,676	2,170	1,044	484
10	.426	4,676	1,992	1,044	445
11	.391	4,676	1,828	1,044	408
12	.359	4,676	1,679	1,044	375
13	.330	4,676	1,543	1,044	344
14	.303	4,676	1,417	1,044	316
15	.278	5,676	1.578	245	68
Total present value			$58,723		$27,424

Therefore, this economic analysis will compare only costs to determine the most favorable alternative.

Alternative 2. - Reclamation ownership. Reclamation personnel determine that equivalent telephone switching equipment can be purchased from a commercial supplier and installed and maintained by force account labor. A tabulation of the costs involved is:

Equipment cost from private supplier: $15,980

Installation and testing of new system at 3 percent of equipment cost: $479

Indirect costs covering Reclamation procurement and finance office costs: $2,397.

Estimated Federal tax credit on contract procurement, 2 percent x $15,980: $230. (Amount of Federal tax the contractor will pay on equipment procurement. Rate computed from Quarterly Financial Report of Manufacturing Corporations.)

Interest during construction; 2 months at 8.91 percent on $15,980: $237.

(Amount of interest Reclamation pays on the estimated contract cost during construction. Construction period estimated at 2 months and interest rate at 8.91 percent is the yield on long-term treasury bonds taken from Treasury Bulletin for January 1979.)

Operation and maintenance annual costs based on experience with similar systems: $600.

Annual allowance of 9.5 percent for Federal income tax calculated using the telephone company's 1979 expense report and computed on the yearly costs of the leased system: (0.095 x yearly cost of leased system).

Net scrap value at end of service life, at 5 percent of new equipment cost (005 x $15,980):-$799

The estimated service life of telephone switching equipment is 15 years.

Summary of costs by year - Alternative 2. -

Year 1:$15,980 + 479 + 2,397- 320 + 237 + 600 + 0.095 x 11,496 = $1,500

Years 2, 3, 4, 5:600 + 0.095 x 9,476 = $1,500

Years 6 to 15: 600 + 0.095 x 4,676 = $1,044

Year 15:600 + 0.095 x 4,676- 799 = $245

Use an interest rate of 8.91 percent (current yield on long-term treasury bonds) to determine the present worth (P) of the costs of the two alternatives.

Cost Comparison, Conclusions, and Recommendations

The analysis shown on the discounting table (table B) can be used to tell several important economic facts about alternatives 1 and 2.

a. The present value of costs of alternative 1 ($58,723) is more than twice that of alternative 2 ($27,424). Since the benefits (services) of the two alternatives are the same, alternative 2 (Government ownership of the switchboard) is the most economical scheme.

b. Circular A-76 comparison criteria (section 7b-3) require that Government costs be at least 10 percent less than leased circuit costs before a Government-owned system can be installed. The ratio of leased circuit costs to adjusted Government-owned costs is therefore

$$\frac{58,723}{27,424 \text{ x } 1.10} = 1.95$$

Clearly, alternative 2 meets the economic test for being the preferred system.

c. What would happen if the projected 15-year service life for the equipment is too long? Note that the total present value of costs for alternative 1 exceeds those of alternative 2 in the 3rd year of the study. This indicates that should obsolescence or other factors make switchboard replacement desirable after only 4 years (for example), alternative 2 is still the preferred economic scheme. This is a comfortable margin for error in service-life estimation.

We conclude that the economic analysis shows considerable savings for Reclamation ownership of the switchboard. However, our final recommendations must depend upon other factors as well. Are Government maintenance forces adequately staffed and training to provide this service? Do management policies permit installation of a Government-owned system? If the answers to such questions are yes, one can strongly recommend that alternative 2 be Implemented.

5.2. Justification for warehouse docking facilities at the Big Water Project Headquarters. -

• Problem.- The maintenance manager is evaluating the feasibility of building loading docks for the warehouse at Big Water Project Headquarters. The building does not have docks and warehousing activities are tedious and expensive. The manager evaluates the lost time and concludes that these docks will save $10,000 annually. The docks will cost $50,000 and take 1 year to complete. The new docks are estimated to have a service life of 7 years. The current annual interest rate is 10 percent. The maintenance manager determines that adequate funds can be programmed for the docks, but wants to ensure the expenditure can be economically justified. The following study is performed.

Benefit/Cost Comparisons, Conclusions, and Recommendations

See the discounting table (table C). The present value of costs ($45,450) exceeds that of benefits ($44,230) over the study period. Therefore, it would not be economical to build the dock facilities. Other factors such as safety, anticipated staff cuts, etc., will also have a significant influence on the decision. Note the following from the discounting table:

a. The 1-year delay in accruing savings (study year 2 rather than study year 1) caused the adverse economic study result, if a way could be found to shorten the construction time, the

Table C. - Discounting table for warehouse docking facility problem

Program year	Discount factor (10%)	Costs	(P)	Benefits	(P)
I	0.909	$50,000	$45,450	$ 0	$ 0
2	.826	0	(Docks in use)	10,000	8,260
3	.751	0	0	10,000	7,510
4	.683	0	0	10,000	6,830
5	.620	0	0	10,000	6,200
6	.620	0	0	10,000	5,640
7	.513	0	0	10,000	5,130
8	.466	0	0	10,000	4,660
Total present value			$45,450		$44,230

docks would become more economically feasible.

b. If the service life of the docks could be extended from 7 to 8 years, they could be economically Justified.

Perhaps the service life could be extended through use of concrete instead of wood. Other alternatives should be considered.

The maintenance manager concludes that the docks cannot be economically justified as proposed. However, other alternatives or modifications may be developed which prove economically feasible. No firm recommendations on the docks can be made until further studies are completed.

6. FURTHER HELP

You have been exposed to several basic economic principles in this bulletin, and by following and understanding the examples, you have an insight on use of economic analysis. The economic principles discussed were selected in the belief that they will be of most use to you, the maintenance manager. No attempt is made to cover all important economic principles; to do so would require the services of a professional economist. Assistance on analysis of maintenance problems is available from the Operation and Maintenance Engineering Branch, Attention D-5850, Denver Office.

For those wishing further study of principles and practices as applied in the Bureau of Reclamation, the following publication is recommended: "A Guide to Using Interest Factors in Economic Analysis of Water Projects." This publication may be ordered from the Denver Office, Attention D-7923A.