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A Comparison of Two Procedures for Evaluating the Economics of Industrial Power Plants

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OAK RIDGE NATIONAL LABORATORY

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CONTENTS

Page

ABSTRACT 1

1. INTRODUCTION 2

2. DISCOUNTED CASH FLOW TECHNIQUES 4

2.1 Aspects of Discounted Cash Flow Methods 4

2.1.1 Concept of equivalence 4
2.1.2 Investment function of the firm 7
2.1.3 Consideration of income taxes 9

2.2 Example 1 — An Illustration of Discounted Cash Flow Analysis 15

2.2.1 Present worth (100% borrowed funds) 18
2.2.2 Internal rate of return (100% borrowed funds) 18
2.2.3 Present worth (50% debt, 50% equity) 20
2.2.4 Internal rate of return (50% debt, 50% equity) 20

3. REVENUE REQUIREMENT METHOD 23

3.1 Introduction 23

3.2 Intent of the Revenue Requirement Method 23

3.3 Assumptions Underlying Comparability of the Two Methods 26

3.4 Example 2 — An Example of the Revenue Requirement Method 27

4. EQUIVALENCE OF THE RR METHOD AND THE PW METHOD 38

4.1 Use of Example 2 to Establish Equivalence 38

4.2 Effect of Differences in Perspective on Example 2 45

5. ANALYSIS OF MULTIPLE ALTERNATIVES 49

5.1 Introduction 49

5.2 Analysis by the Present-Worth Method (Nonregulated Firm 50

5.3 Analysis by the Revenue Requirement Method (Regulated Firm) 53

5.4 An Illustration of Reversal in Preference Orderings 54

6. DEALING WITH COMPLICATIONS IN ECONOMIC EVALUATIONS 56

6.1 Effects of Accelerated Depreciation and Minimum Asset Depreciation Range Life 56

6.2 Example 3 — Treatment of Inflation 58

6.3 Consideration of Investment Tax Credits 68

Page

6.4 Consideration of Salvage Values 70

6.5 Summary of Dealing with Complications 71

7. CONCLUSIONS AND RECOMMENDATIONS 72

REFERENCES 75

APPENDIX A. TERMS USED IN ENGINEERING ECONOMY 79

APPENDIX B. BASIS AND CERTAIN FEATURES OF THE DISCOUNT TECHNIQUE 85

APPENDIX C. INTERPRETATION OF CAPITAL RECOVERY COSTS 91

APPENDIX D. GENERALIZED EQUATIONS FOR THE EQUIVALENCE OF THE REVENUE REQUIREMENT METHOD AND THE PRESENT-WORTH METHOD 95

A COMPARISON OF TWO PROCEDURES FOR EVALUATING THE ECONOMICS OF INDUSTRIAL POWER PLANTS

W. G. Sullivan

ABSTRACT

The purpose of this report is to compare two economic evaluation procedures that are commonly used to evaluate engineering alternatives for industrial power plants. The procedures are: discounted cash flow analysis (e.g., present worth and internal rate of return) and the revenue requirement method. The former procedure tends to be used by nonregulated, for-profit companies, while the latter is widely accepted in regulated utilities. For purposes of this study the aim of each analytical procedure is the same, namely, a conceptually sound assessment of economic differences among engineering projects such that the least-cost (or most profitable) project can be selected.

It is demonstrated herein that the two procedures, when based on the same assumptions, produce the same preference rankings among alternatives being considered. In addition, the same incremental projected levelized cost streams are generated. Furthermore, it is shown that the effect of inflation and special tax incentives can be readily evaluated with both procedures and that identical results are obtained. For mutually exclusive alternatives, it is shown that the ratio of present worth of costs between the alternatives is identical to the ratio of levelized revenue requirements for selected debt-equity financing schemes. It is concluded that both methods of project evaluation provide consistent results in terms of relative economic differences among alternatives being considered.

It should be noted that the quantification of economic differences (e.g., dollars per million Btu) among industrial power plants is not necessarily synonymous with estimating costs for the purpose of establishing a selling price for a commodity or service. The focus of this report is centered on evaluation of after-tax economic differences among alternatives rather than development of estimates of a project's before-tax operating revenues that could be used, in turn, to formulate a firm's policy regarding energy prices.

1. INTRODUCTION

The basic aim of this report is to compare two commonly used procedures for evaluating the economics of large-scale engineering projects such as industrial power plants. They are (1) discounted cash flow analysis (e.g., present worth), frequently employed by nonregulated private businesses, and (2) the revenue requirement methodology, which is unique to regulated utilities in the private sector. After briefly describing each procedure, it is shown through numerous example problems that they provide identical cost-profitability differences among alternatives when underlying assumptions are the same. Both methods are then used to evaluate multiple alternatives, and it is shown that the procedures produce consistent results (i.e., identical ratios of evaluation criteria are obtained). Then several tax-related complications regarding application of the methods are investigated with tabular analysis formats, and results are verified with a computer code.

In this report it is assumed that the reader is somewhat familiar with both methods. As used here, the aim of each procedure is identical, namely, the quantification of relevant economic differences among mutually exclusive* industrial power plant designs. This aim is not necessarily synonymous with estimating costs of energy produced by each plant for purposes of establishing its selling price. This subtle distinction must be kept in mind as one reads the report.

To narrow the scope of the discussion that follows, only two discounted cash flow techniques are presented: present worth and internal rate of return. Because of computational difficulties with the internal rate of return technique, emphasis in this report is placed on present-worth analysis. One major shortcoming of internal rate of return is demonstrated in example 1 (to follow).

Probably the best-known text dealing with discounted cash flow analysis is *Principles of Engineering Economy*.[1] Concerning the revenue requirement methodology, the most authoritative description is found in *Profitability and Economic Choice*.[2]

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*A set of mutually exclusive alternatives is one where a single alternative is chosen as best, thereby eliminating the rest of the set.

The report is organized to achieve the aforementioned aim through several example problems. Briefly, these problems provide the framework for comparing the two economic evaluation procedures in a logical sequence of steps. Example 1 demonstrates why the present-worth method is chosen over internal rate of return for purposes of performing discounted cash flow analyses. Example 2 illustrates several methods of computing levelized revenue requirements and is also used to show the comparability of the two procedures under study. Finally, a third example is used to show how various complications (such as accelerated depreciation and inflation) are dealt with in each procedure.

2. DISCOUNTED CASH FLOW TECHNIQUES

2.1 Aspects of Discounted Cash Flow Methods

2.1.1 Concept of equivalence

Analysis of cash flow patterns begins with the identification of feasible alternatives to accomplish a stated mission, followed by the quantification of relevant costs and benefits of each over its life cycle and the subsequent reduction of costs and benefits to a single figure of merit. Here two figures of merit are considered: present worth and internal rate of return. These criteria involve principles of time value of money with an appropriate interest rate such that the *equivalent* value of each alternative can be assessed. (Two things are equivalent when they have the same effect.) The process of reducing all cash flows to an equivalent basis of comparison in view of the earning power of money is often termed "discounting" — hence the generic name, discounted cash flow analysis. Definitions of technical terms used in engineering economic analysis are provided in Appendix A.

The reduction of engineering alternatives to a common monetary base is necessary so that the intuitive differences between alternatives become objective and quantifiable differences in view of the time value of money. Because decisions are based on differences between alternatives, the selection of a comparative method capable of reflecting relevant economic differences is imperative.

To place prospective receipts and/or disbursements of two or more alternatives on an equivalent basis, interest formulas and tables must be properly used. The economic problem of establishing equivalence involves the measurement, at a single point in time, of a series of cash flows characterized by different dollar amounts and different timing. Relevant cash flows are those that are *incremental* to the acceptance of an alternative. They are measured by the difference between cash flows that exist if the alternative were accepted and the cash flows that would exist if it were rejected.

The net present worth of an alternative is defined to be the discounted value of cash inflows less cash outflows at a point that is considered to be the "present." In theory, the net present worth of an alternative is a measure of how much money will have to be put aside now to provide for one or more future expenditures. It is assumed that such cash placed in reserve earns interest at a rate at least equal to a firm's cost of capital. To find the present worth (PW) of a series of cash receipts and/or disbursements, it is necessary to discount future amounts (F) to the present by using an interest rate for the appropriate number of periods (years, for example) in the following manner:

$$PW = F_0(1 + i)^0 + F_1(1 + i)^{-1} + F_2(1 + i)^{-2} + \ldots + F_n(1 + i)^{-n} + \ldots + F_N(1 + i)^{-N} , \qquad (1)$$

where

i = effective interest rate per period,

n = an index for each period ($0 \leqslant n \leqslant N$),

N = number of periods.

With this general relationship, the present worth of future cash flows can be determined. The net present worth of all cash flows is the algebraic sum of the present worths of individual receipts and disbursements. The relationship given in Eq. (1) is based on the assumption of a constant interest rate throughout the life of a particular project. If the interest rate is assumed to change, the present worth must be computed in two or more steps.

In certain circumstances wherein a single interest rate is used, the present-worth method is based on the assumption that intermediate cash inflows generated by a project during its life are reinvested at a rate of return equal to that being used to discount cash flows. This assumption is implicit in the utilization of the present-worth method, and if it does not apply, the present-worth method cannot be used as a reliable measure of a project's profitability. If the intermediate cash inflows were reinvested at an interest rate other than i in Eq. (1), a different net present worth would result.

The higher the interest rate and the further into the future a cash flow occurs, the lower is its present worth. This is shown graphically in Fig. 1.

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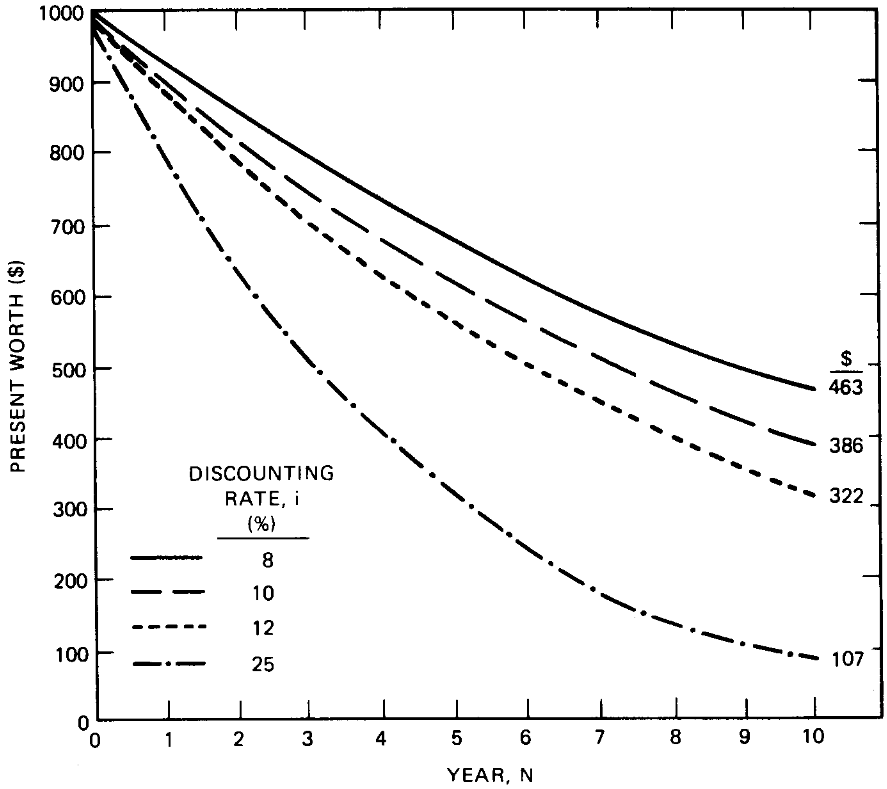

Fig. 1. Present worth of $1000 received in year N at an interest rate of i%.

Year-end cash flows occurring before the base date (i.e., time zero) have a negative value of n in Eq. (1) and must therefore be compounded forward to the base date. After all cash flows have been reduced to their equivalent value at the base date, an algebraic sum yields the net present worth. It should be stressed that common (i.e., equal) service periods for alternatives under consideration are prerequisite to use of the present-worth method.

In summary, the present-worth method identifies the alternative that maximizes an absolute difference between discounted cash receipts (inflows) and discounted cash expenditures (outflows). When only negative cash flows (disbursements) are present, the present-worth method provides a means for selecting the investment opportunity which will minimize discounted cash flow at the base date. The advantages and disadvantages of present-worth analysis can be summarized in terms of numerous assumptions that are inherent to the method:

Advantages	Disadvantages
Permits use and return of funds at the actual cost of capital to the firm	Requires assumptions regarding life of the project and cost of capital to the firm
Permits alternatives to be correctly ranked in most capital budgeting problems	Difficulty may exist in understanding the significance of present-worth lump sums
Avoids the problem of interpreting multiple rates of return (caused by more than one reversal in sign of the cash flow)	May give incorrect results if service periods are not identical for all alternatives being compared
Avoids the problem of taking explicit account of differences between lending and borrowing rates throughout life of the project (i.e., a perfect capital market is assumed)	Sensitive to overestimates in the interest rate (when present worth is being used to rank investment desirability)

2.1.2 Investment function of the firm

The subject of this section concerns capital investment decisions made by two types of firms: nonregulated and regulated. The difference in purpose of investment analysis by the PW method, which is heavily used by nonregulated industries, and the revenue requirement (RR) method, which is dominant in regulated utilities, is indeed subtle: to maximize future wealth of the owners of a company and to minimize cost of service to customers respectively. This difference in perspective is essential to understand, because it lies at the heart of most dissimilarities that arise between the two methods.

The PW method further is valid only when the firm operates in a perfect capital market where lending rates equal borrowing rates and transaction costs are negligible. In a perfect capital market the present-worth criterion may be used to select the most profitable investment opportunity, and such selection can occur *independently* of how the project is to be financed. For this reason, present-worth analysis is often used to evaluate projects where 100% equity financing is assumed, even though the firm's capitalization structure includes debt capital. A second reason is that equity capital is the most expensive source of new funds; and by considering a project to be financed 100% with equity, a very conservative position is taken regarding the acceptability of any given proposal.

In contrast, the RR method takes explicit recognition of the firm's historical cost of capital, which usually includes a sizable fraction of debt capital. Thus the RR method endeavors to reflect how the project (on the average) will be financed, and the resultant after-tax cost of capital is clearly affected by the financing function of the utility. It is now apparent that the RR method is *not independent* of historical financing practices of the firm; for this reason the investment function of the firm is closely related to the financing function. This is an important difference between the PW and RR methods as they are used in practice.

For purposes of this report, the debt-equity balance that is integral to the RR method is taken into account in all subsequent PW analyses. In this manner the comparability of the two methods can be demonstrated through a series of example problems. In most PW analyses conducted by competitive industry, it is noted that debt-equity considerations are usually not taken into account, as will be done throughout this report. Instead, the conservative assumption is often made that new projects will be financed *entirely* with equity funds.

Return on equity represents an annual amount expected by stockholders for the use of capital that they invest in the company. The rate utilized to calculate return on equity is not a precise number because it varies with current market conditions and the financial performance of the firm. In fact, there is no guarantee that any return whatsoever will be paid to stockholders.

Because it is assumed in this report that depreciation is used to repay debt principal and to "buy back" (liquidate) stockholder's equity over the life of a project, the return on equity each year is based on a certain percentage of the unrecovered investment and *not* the total original investment. In this manner a project "recovers" its original investment over its useful life through systematic repayment of debt principal and equity made possible by annual depreciation write-offs. Such amortization of an investment is considered to be a noncash cost of operating a business and is reflected in selling prices of goods or services produced. However, these allocations of noncash costs of a capitalized asset are not directly included in the estimated cash flow of a project except as they affect the determination of income taxes or are included in an item's selling price, which translates into operating revenues generated each year. This is further explained later in this section.

In regard to the firm's debt obligations, a fixed annual return on a bond's face value is guaranteed to investors for the life of a bond. This return is less than that expected by stockholders because payment of interest and recovery of the initial investment is practically assured and is therefore essentially risk-free. Interest on debt is a cost of business to a firm and must be paid periodically, whereas return to stockholders is variable, subject to many internal and external factors.

In summary, the amount of debt and equity financing utilized by a firm affects its after-tax cost of capital, and this consideration often has an important bearing on the economic desirability of any given project.

2.1.3 Consideration of income taxes

Income taxes resulting from the profitable operation of a firm normally are taken into account in evaluating large engineering projects. The reason is quite simple; income taxes associated with a proposed project represent a major cash outflow that should be considered along with other cash inflows and outflows in assessing the overall economic attractiveness of that project. There are many other taxes not directly associated with the income-producing capability of a new project (e.g., property taxes and excise taxes), but they are usually negligible when compared with state and federal income taxes. Because the capitalization structure of a firm influences the annual income taxes that must be paid, this report deals with debt and equity considerations and their effect on cash flows, including income taxes.

For corporations in the United States, the basic tax calculation involves the determination of ordinary income tax liability. *Ordinary income* results from operating revenues, less cost of goods sold minus deductions allowed by law. *Capital expenditures* are not classified as deductible expenses but instead are recovered by amortizing (depreciating) the investment.

The procedure followed in determining after-tax cash flows, including income tax cash flows, is illustrated in Fig. 2. Here it can be seen that operating income of a project (operating revenues less operating expenditures) is first computed. Second, interest on debt is subtracted along with noncash expense items (depreciation) to arrive at taxable income. The federal income tax rate, which was 48% in 1978 for corporations having taxable income over $50,000, is next multiplied by net (i.e., taxable) income to determine the federal income tax. An analogous procedure is utilized to determine state income tax, where applicable. Figure 2 further shows that depreciation, deferred taxes, and reinvested earnings are employed to finance new construction projects and replacements of old assets. The stockholder is concerned with the after-tax profitability of investments as they affect net worth of the firm and dividends paid.

To formalize the procedure suggested above for determining the net income before income taxes and after-tax cash flow of a project, the following notation and equations are applicable.

For any given period n in the sequence of the project life, n = 1, 2, ..., N, let

G_n = operating revenues from the project; this is the cash inflow to the project resulting from operating the project during period n;

E_n = cash outflows during year n for all deductible expenses, excluding interest paid on project indebtedness;

D_n = sum of all noncash items chargeable during n, such as depreciation (which can be book or tax depreciation, depending on what type of industry is involved);

I_n = cash interest paid during year n on borrowed funds;

P_n = repayment of principal of borrowed funds during year n;

t_e = effective ordinary income tax rate (federal, state, and other);

T_n = income taxes paid during year n;

Y_n = net cash flow from the project during year n.

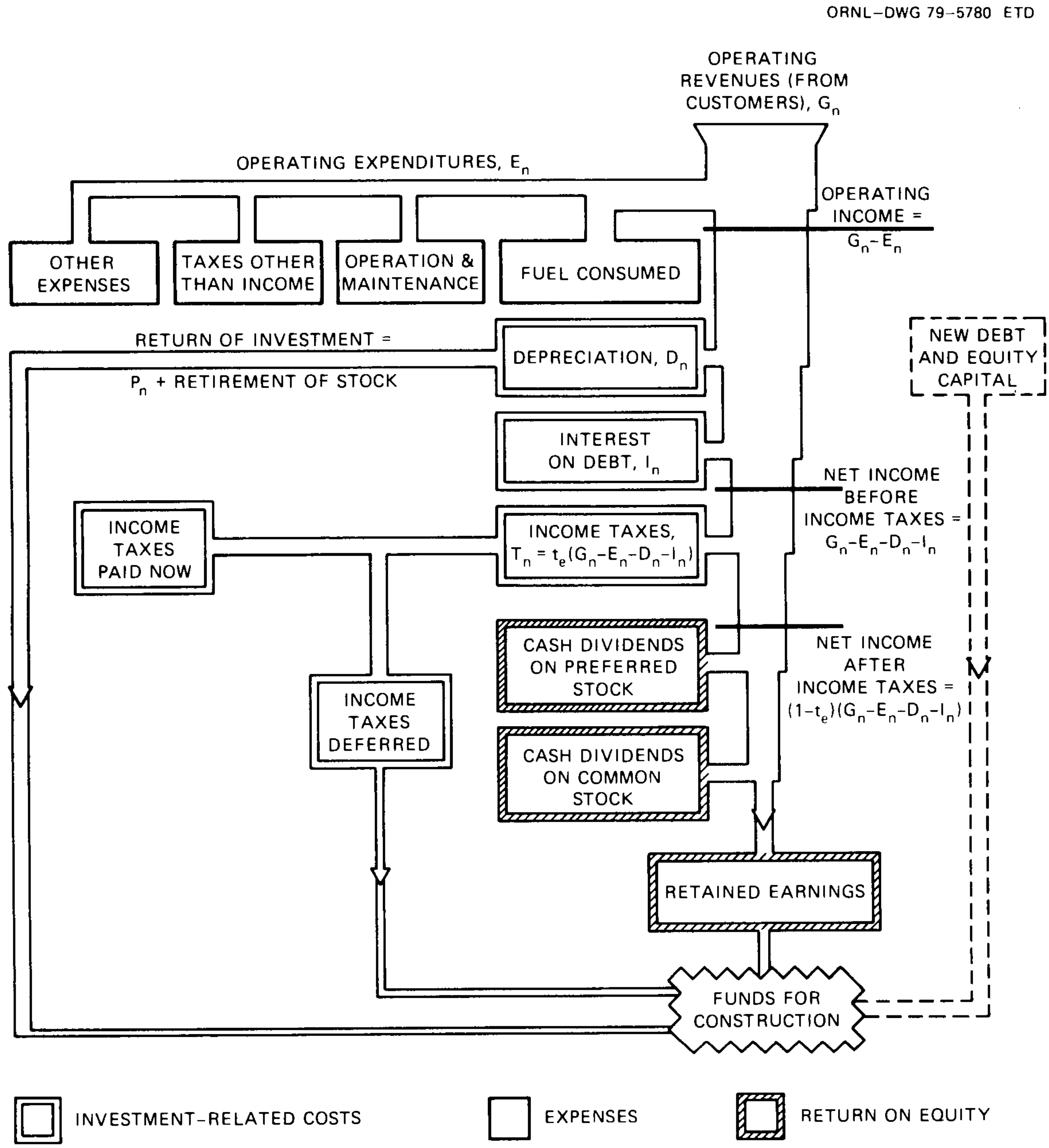

Fig. 2. Graphical summary of determination of net income after income taxes (return on equity).

When state income taxes are deductible from taxable income computed for federal income tax determination, the *effective* ordinary income tax rate is defined as follows:

$$t_e = s + (1 - s)f \ , \tag{2}$$

where

s = state income tax rate expressed as a decimal,

f = federal income tax rate expressed as a decimal.

Because the net income before taxes (i.e., taxable income) is $(G_n - E_n - D_n - I_n)$, as seen in Fig. 2, the ordinary income tax liability is computed with Eq. (3):

$$T_n = (G_n - E_n - D_n - I_n)t_e \ , \tag{3}$$

and the after-tax net income is then simply taxable income minus the income tax liability, or

$$\underbrace{(G_n - E_n - D_n - I_n)}_{\text{taxable income}} - \underbrace{(G_n - E_n - D_n - I_n)t_e}_{\text{income tax}} \ ,$$

$$\text{or after-tax income} = (G_n - E_n - D_n - I_n)(1 - t_e) \ . \tag{4}$$

The *after-tax cash flow* associated with equity capital invested in a project equals the net income after taxes plus noncash items such as depreciation and less repayment of loan principal:

$$Y_n = (G_n - E_n - D_n - I_n)(1 - t_e) + D_n - P_n \ . \tag{5}$$

Equation (5) for the after-tax cash flow can be stated in an alternative form by combining the depreciation terms; thus

$$Y_n = (G_n - E_n - I_n)(1 - t_e) + D_n t_e - P_n \ . \tag{6}$$

Note that the next to the last term in Eq. (6) is simply the effective tax rate, t_e, times the depreciation deduction, D_n; this is the equivalent cash contribution of the depreciation deduction to the total after-tax cash flow, Y_n. In addition, the repayment of loan principal is reflected in Eqs. (5) and (6), so that Y_n represents the after-tax return *on* equity capital and the return (i.e., retirement) of equity over the life of the project.

In many economic analyses of engineering projects, after-tax cash flows are computed in terms of *before-tax cash flows*, Y'_n:

$$Y'_n = G_n - E_n - I_n \; ; \tag{7}$$

$$T_n \text{ [from Eq. (3)]} = (G_n - E_n - D_n - I_n)t_e \; ,$$

$$Y_n = Y'_n - T_n - P_n \; , \tag{8}$$

or

$$Y_n = G_n - E_n - I_n - (G_n - E_n - D_n - I_n)t_e - P_n \; .$$

Finally, it is seen that $Y_n = (G_n - E_n - I_n)(1 - t_e) + D_n t_e - P_n$, which is identical to Eq. (6).

Table 1, which reflects the operations implied by Eq. (6), can be used to summarize and simplify determination of a project's annual after-tax cash flow, including the after-tax cost of capital investments and project financing.

Column 1 contains the end-of-year notation, beginning at the time a facility is commercially operated. The time at which the decision is made to initiate or not to initiate the project is referred to as n = 0, or "the present." An n = 0 row is included in Table 1 to represent the *investment cash flow*, which includes investment tax credits and borrowed funds. Column 2 contains the estimated values of operating revenue, year by year; column 3 is projected cash expense deductions, and column 4 is the cash interest deductions. Column 5 is called operating income, and it simply is operating revenue minus cash expenses. Column 7 is called the after-tax operating income and is the operating income minus the income taxes. Depreciation expense and other noncash expense items are recorded in column 8, or in a multicolumn equivalent of column 8. Column 9 is the equivalent cash inflow due to the savings in income taxes resulting from the noncash expenses in column 8 and equals column 8 (as a total) times the effective income tax rate, t_e. Repayment of borrowed loan principal (a negative cash flow), calculated by an acceptable method to the firm, is entered in column 10. Column 11 is then the total after-tax cash flow, which also includes cash flows related to a project's capital investment.

Table 1. Format for calculating after-tax cash flows, incorporating Eq. (6) operations

(1) Year n	(2) Operating revenue (year 1 — N); capital investment (year 0) G_n	(3) Cash expenses (except interest and income taxes) E_n	(4) Interest expense I_n	(5) Operating income after interest charges (2) — [(3) + (4)]	(6) Ordinary income tax $(5)\cdot(t_e)$	(7) After-tax operating income (5) — (6)	(8) Depreciation expense D_n	(9) Tax saving from depreciation $(8)\cdot(t_e)$	(10) Repayment of loan principal P_n	(11) Total after-tax cash flow, Y_n (and investment cash flows) (7) + (9) — (10)
0										
1										
2										
•										
•										
•										
N										

An alternative tabular format, based on Eq. (8), is provided in Table 2 and is utilized in the example problems to follow. (The use of Table 1 or Table 2 in present-worth studies is strictly a matter of personal preference.)

2.2 Example 1 — An Illustration of Discounted Cash Flow Analysis

This example demonstrates (1) debt-equity financing considerations, (2) computation of after-tax cash flow, and (3) reduction of after-tax cash flow to an equivalent figure of merit with the present-worth and internal rate of return techniques. The example also demonstrates a major drawback of the internal rate of return technique when debt-equity considerations are integral to an economic evaluation. Because of this shortcoming, the PW method is recommended in discounted cash flow analyses. Finally, the manner in which debt and equity are treated in example 1 is consistently utilized in present-worth studies throughout this report.

Suppose a machine costing $11,000 can be financed entirely by borrowed funds or by 50% debt and 50% equity. The loan is to be repaid at the rate of $2000 each year for the first four years and $3000 at the end of the fifth year. Interest charges are 10% of the *unpaid*, beginning-of-year balance of the loan. Depreciation is figured on a straight-line basis, and the tax life is five years; the estimated salvage value is $1000. The expected annual operating revenue attributable to the machine *before* deducting interest charges and operating expenses is $10,000, and the effective income tax rate is 50%. It will be assumed that operating revenues are independent of the financing plan in effect. Operating costs amount to $3000 per year. It is desired to calculate the after-tax cash flows of both financing plans so that observations regarding the choice of a suitable criterion of economic attractiveness can be made. Note that because loan principal is being repaid in a stated amount each year, both columns 4 and 5 of Table 2 are used. Table 3 summarizes the calculations required to determine after-tax cash flow.

Based on 100% borrowed-funds financing of this machine, the after-tax cash flow (ATCF) of Table 3 is now evaluated with two techniques in widespread use — present worth and internal rate of return.

Table 2. Format for determining after-tax cash flows, based on Eq. (8) operations

(1) Year n	(2) Operating revenue (year 1 — N); capital investment (year 0) G_n	(3) Cash expenses (except interest and income taxes) E_n	(4) Interest expense I_n	(5) Repayment of loan principal P_n	(6) Operating income after interest charges, or before tax cash flow (2) — [(3) + (4)]	(7) Depreciation expense D_n	(8) Taxable income (6) — (7)	(9) Income tax $t_e \cdot (8)$	(10) After-tax cash flow, Y_n (and investment cash flows) (6) — (5) — (9)
0									
1									
2									
•									
•									
•									
N									

Table 3. Example 1 — After-tax analysis of machine financing with 100% borrowed funds

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Year n	Operating revenues (and investment cash flow) G_n	Cash expenses E_n	Loan cash flow		Before-tax cash flow = (2) − [(3) + (4)] in yr 1–5 = (2) − [(3) + (5)] in yr 0	Depreciation D_n	Taxable income (6) − (7)	Income tax t_e(8)	After-tax cash flow, including investment cash flow (6) − (5) − (9)
			Interest I_n	Principal P_n					
0	−11,000[a]			+11,000	0				0
1	10,000	3000	1100	2,000	5900	2000	3900	1950	1950
2	10,000	3000	900	2,000	6100	2000	4100	2050	2050
3	10,000	3000	700	2,000	6300	2000	4300	2150	2150
4	10,000	3000	500	2,000	6500	2000	4500	2250	2250
5	10,000	3000	300	3,000	6700	2000	4700	2350	1350
5	1,000[a] (salvage)				1000		0	0	1000[a]

[a]Investment cash flow.

2.2.1 Present worth (100% borrowed funds)

With an after-tax minimum attractive return of i = 15%, the PW of the machine's ATCF is

$$\begin{aligned} PW\ (15\%) &= 1950\ (P/A,\ 15\%,\ 5) + 100\ (P/G,\ 15\%,\ 5) \\ &= 1950\ (3.3522) + 100\ (5.775) \\ &= \$7114.29, \end{aligned}$$

where

$$(P/A,\ 15\%,\ 5) = \frac{(1.15)^5 - 1}{0.15\ (1.15)^5} ,$$

$$(P/G,\ 15\%,\ 5) = \frac{1}{0.15\ (1.15)^5} \left[\frac{(1.15)^5 - 1}{0.15} - 5 \right] .$$

2.2.2 Internal rate of return (100% borrowed funds)

In the following equation, the internal rate of return is determined:

$$0 = 1950\ (P/A,\ IRR,\ 5) + 100\ (P/G,\ IRR,\ 5) ,$$

where

$$IRR = \infty \text{ (no internal rate of return can be determined) } .$$

However, the internal rate of return is not defined because there is no equity investment and no other net cash outflow at the end of any year in the life of the project.

To illustrate further how Table 2 might be used when debt and equity are involved, the same machine financed with 50% debt capital and 50% equity capital is considered. Table 4 summarizes the information necessary for this analysis. Notice that annual repayment of loan principal is half of that shown earlier in Table 3, since only 50% of the funds are borrowed.

Table 4. Example 1 — After-tax analysis of machine financing with 50% borrowed funds

(1) Year n	(2) Operating revenues (and investment cash flow) G_n	(3) Cash expenses E_n	(4) Loan cash flow: Interest I_n	(5) Loan cash flow: Principal P_n	(6) Before-tax cash flow = (2) − [(3) + (4)] in yr 1–5 = (2) − [(3) + (5)] in yr 0	(7) Depreciation D_n	(8) Taxable income (6) − (7)	(9) Income tax $t_e(8)$	(10) After-tax cash flow, including investment cash flow (6) − (5) − (9)
0	−11,000[a]			+5500	−5500[a]				−5500[a]
1	10,000	3000	550	1000	6450	2000	4450	2225	3225
2	10,000	3000	450	1000	6550	2000	4550	2275	3275
3	10,000	3000	350	1000	6650	2000	4650	2325	3325
4	10,000	3000	250	1000	6750	2000	4750	2375	3375
5	10,000	3000	150	1500	6850	2000	4850	2425	2925
5	1,000[a] (salvage)				1000		0	0	1000[a]

[a] The investment which can be depreciated is \$11,000 less salvage; the equity portion of the \$11,000 investment is \$5500, upon which a rate of return is to be calculated.

2.2.3 Present worth (50% debt, 50% equity)

Based on Table 4 results, the present worth of ATCF at i = 15% is

$$\begin{aligned} PW\ (15\%) &= -5500 + 3225\ (P/A,\ 15\%,\ 5) + 50\ (P/G,\ 15\%,\ 5) \\ &\quad + 500\ (P/F,\ 15\%,\ 5) \\ &= -5500 + 3225(3.3522) + 50(5.775) + 500(0.4972) \\ &= \$5848.20\ , \end{aligned}$$

where

$$(P/F,\ 15\%,\ 5) = \frac{1}{(1.15)^5}\ .$$

2.2.4 Internal rate of return (50% debt, 50% equity)

Using the following equation

$$0 = -5500 + 3225\ (P/A,\ IRR,\ 5) + 50\ (P/G,\ IRR,\ 5) + 500\ (P/F,\ IRR,\ 5)\ ,$$

by trial and error, IRR ≃ 0.53.

The present worth has decreased to about \$5850, and the internal rate of return can be calculated to be roughly 53%. If 100% equity financing were used, the ATCF would be as follows:

Year	ATCF	
0	−11,000	
1	4,500	
2	4,500	
3	4,500	PW (15%) = \$4581.20
4	4,500	Internal rate of return = 31%
5	4,500	
5	1,000 (salvage)	

Thus we see an interesting phenomenon developing as the debt financing pattern is varied. Graphically, the trend is illustrated in Fig. 3.

As the amount of debt financing increases, the rate of return becomes disproportionately larger, equaling infinity when 100% debt is

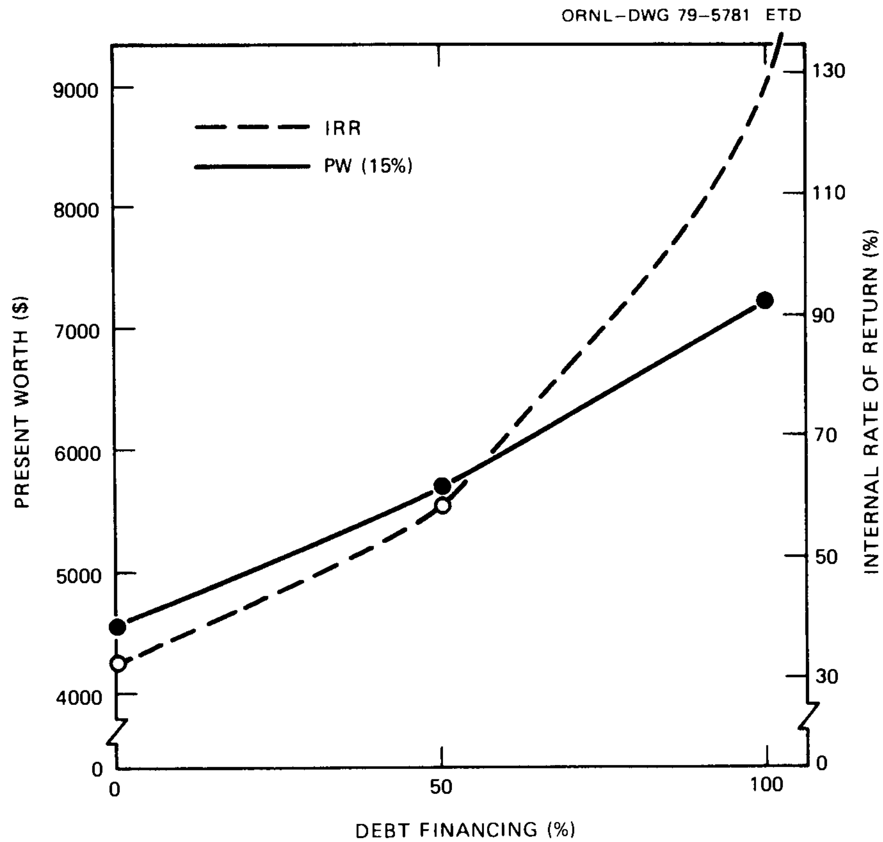

Fig. 3. Present worth and internal rate of return as a function of percent debt financing.

involved. This is a questionable indication of economic profitability. As a consequence, when debt financing is an integral part of the analysis, the present-worth technique is customarily used to measure long-term profitability of an investment opportunity. From Fig. 3 it can be seen that present worth is a suitable project selection criterion when debt financing is explicitly considered. The investment required after borrowing is taken into account is provided from equity sources.

Note that the after-tax cost of debt capital in this example is 10% $(1 - t_e)$ = 5%. This is true since annual interest expense in Table 1 is deducted as a business expense prior to calculating taxable income and income taxes. Because new capital expenditures are expected to earn at least a specified rate of return (often referred to as the minimum attractive rate of return), the benefits of debt financing are generally favorable when the after-tax cost of debt capital is less than this minimum expected return. For example, if the minimum attractive rate of return after taxes is 15%, the use of debt capital costing 10% before taxes is very attractive. This is apparent in the two financing plans considered above.

The important conclusion from example 1 is that internal rate of return, as a measure of project profitability, tends not to reflect the true merits of a project when large amounts of debt capital are considered in after-tax analysis of discounted cash flows. Hence the present-worth technique is used throughout the remainder of this report.

3. REVENUE REQUIREMENT METHOD

3.1 Introduction

Utility investment decisions in the private sector are affected by the fact that the cash flow these companies generate is influenced by regulatory commissions. A privately owned utility differs from other private businesses in that it is permitted by a regulatory body to earn a maximum fair and reasonable rate of return on its investments. Other business ventures that are not monopolistic in nature do not have such restrictions. Utilities must also furnish services on demand to customers in their service areas. Consequently, a regulated utility cannot omit a segment of the market even if a better return could be earned in another area. Thus the utility is not free to withdraw its investment from the regulated area.

This kind of regulated monopoly structure requires that the utilities generate enough revenues to cover their costs and to allow a reasonable return on the invested capital. In practice, the application of this markup pricing formula frequently is difficult and often leads to litigation. Whether any particular outlay is a reasonable cost, for example, is a source of controversy. The regulatory body often reviews salaries as well as the expenditures on specific components in the production process. If labor rates and fuel costs rise sharply, there may be long delays before the increased costs can be passed on to the customer in the form of higher rates. In the intervening period, the return may be less than fair and reasonable. Consequently, these cost increases cannot readily be corrected in the *short run* because revenues permitted by the regulatory body are "fixed."

3.2 Intent of the Revenue Requirement Method

As with the present-worth method, the revenue requirement (RR) method of capital investment analysis is generally appropriate for situations where several mutually exclusive alternatives are capable of generating identical services (and hence revenues when the price structure is fixed).

Revenues produced by the project must be large enough to ensure a satisfactory rate of return on the total investment. The *intent* is to select the alternative that minimizes present worth of costs over the stated study period. These costs include capital costs and recurring expenses such as insurance, fuel, maintenance, property taxes, and income taxes.

The method involves the description of each alternative in terms of uniform annual required costs and return obligations to investors that it is expected to generate. These costs must be exactly met by revenues. Required revenue is defined as the annual cash inflow realized through the sale of a product or service that causes the net present worth of the project to be zero. Hence *the project selection criterion is to minimize the present worth of the revenue requirement.* This is accomplished by reducing all costs (investment and recurring) to their annual equivalent value (i.e., the revenue requirement), such that an after-tax return on total investment is equal to the minimum rate of return requirement expected by investors.

The total revenue requirement for an alternative consists of carrying charges (CC) resulting from capital investments that must be amortized, and all associated expenses that recur periodically. Carrying charges are synonymous with the annual costs of financing an investment over its life and include the following:

1. book depreciation (return *of* investment to bondholders and stockholders),
2. return *on* investment (to bondholders and stockholders),
3. income taxes.

Therefore, investment costs must be converted to an annual carrying charge so that investment dollars and annual expense dollars resulting from fuel consumption, maintenance, insurance, and so forth can be added together to determine the minimum revenue requirement for a particular alternative. The general relationship for determining the revenue requirement of an alternative is

$$RR = CC + \text{all recurring annual expenses} \; . \tag{9}$$

A graphical portrayal of how the minimum revenue requirement is determined from its components (capital costs, operating costs, profit incentives, and taxes on profit incentives) is provided in Fig. 4. Here it can be seen that the minimum revenue requirement is the revenue that must be obtained to cover all expenses incurred, including the firm's minimum acceptable return, which consists of interest payments to bondholders and a return to stockholders. For a venture to be financially viable, it must generate revenue at least sufficient to meet the minimum RR, and, hopefully, it will produce enough revenue to yield a profit to the company. The intent of the RR method, for purposes of this report, is to select the investment proposal from a mutually exclusive set that *minimizes* the revenue requirement as depicted in Fig. 4.

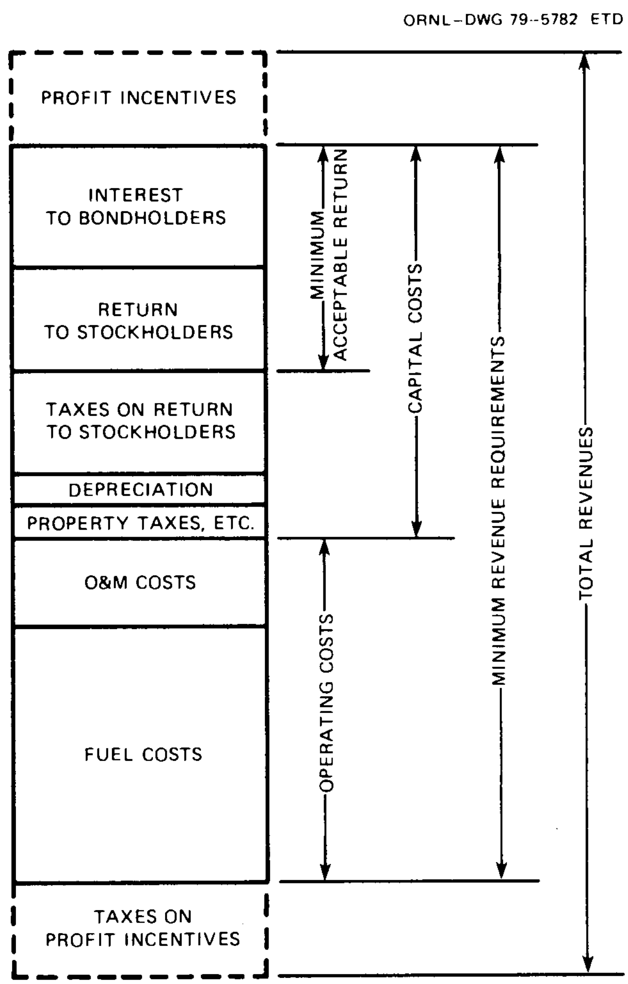

Fig. 4. Components of revenue requirement method.

3.3 Assumptions Underlying Comparability of the Two Methods

A basic assumption utilized throughout this report is that benefits associated with alternatives under consideration *are identical*. That is, the level of service and resultant revenues (if any) are the same for all mutually exclusive proposals. Because they are common to all plans, benefits can be dropped from the analysis. Consequently, the aim is to minimize present worth of costs at a discount rate equaling the return to stockholders, or equivalently to minimize the present worth of the revenue requirement at a discount rate equaling the tax-adjusted average cost of capital. (For purposes of this report, revenue requirements are discounted at the tax-adjusted cost of capital. Justification of this discount rate is provided in Appendix B.)

It should be emphasized that when the above assumption is not valid, differences in benefits realized by each alternative must be explicitly taken into account. Insofar as possible, benefits should be quantified in monetary terms. The PW method can readily deal with unequal benefits and unequal costs in the comparison of alternatives by adopting the criterion of selection as *maximization* of net present worth. If the net present worth is greater than zero, the respective project is economically acceptable. On the other hand, the RR method deals primarily with the special case in which anticipated benefits (i.e., level of service provided) from mutually exclusive alternatives are equal. Furthermore, the stream of benefits is constant over time. The selection criterion is *minimization* of the revenue requirement. Conceptual problems are introduced into the analysis of revenue requirements when nonidentical benefits among alternatives must be taken into account as they vary irregularly over time.

Another assumption utilized throughout this report is that the minimum acceptable return (MAR) to a regulated utility is equal to the return on the company pool of investors' committed capital (ref. 2, pp. 29–56). This condition is tantamount to assuming a risk-free investment opportunity. It greatly simplifies the analysis of projects because no "profit incentive" needs to be considered in Figs. 4 and 5. When risk to the investor is assumed to be negligible, discounting is performed at i',

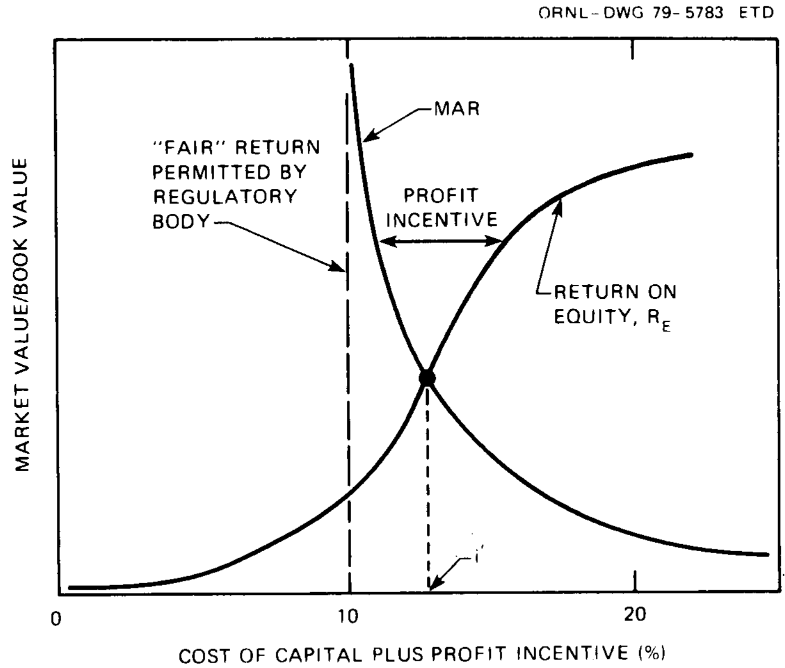

Fig. 5. Relationship between MAR and return on equity for a regulated utility.

as indicated by Fig. 5 and discussed in Appendix B. (Throughout this report, i′ is defined to be the tax-adjusted average cost of capital to the utility.) As the riskiness of the investment increases, the profit incentive increases and a higher discount rate is used. Therefore, it is assumed in this report that differential risks across alternatives being considered are negligible, so that all discounting is based on i′.

As seen in Fig. 5, the assumption that MAR = R_E holds at the point where the curve of return on equity intersects the MAR curve. By making this assumption, it is possible to evaluate the present worth of a project at a firm's return on equity (R_E) and to show that this is equivalent to evaluating a project's revenue requirement at the tax-adjusted average cost of capital to a utility (i′).

3.4 Example 2 — An Example of the Revenue Requirement Method

Various equations are given in this section for determining the revenue requirement of a proposed engineering project. The equations yield the amount of taxes that would be experienced if actual revenues were equal to the total revenues needed to satisfy an established after-tax rate-of-return requirement. Revenue requirements for income taxes arise because part of the return to investors (i.e., the return on equity) is considered profit for income tax purposes. But return on equity is an after-tax amount required by stockholders. As a result, revenue requirements must allow for payment of income taxes on the return to stockholders, after deducting all operating expenses, such that net income remaining after taxes will satisfy investors and attract new capital when needed.

Underlying the equations that follow are these assumptions:

1. Total investment in an asset during any one year will be equal to its *book value* during that year (i.e., the market value will be equal to the book value).
2. Amount of debt capital invested in an asset during any one year will be a constant fraction of its book value during that year.
3. Equity and debt capital involve fixed rates of return throughout the life of the project.
4. Book depreciation charges are used to retire (liquidate) stock issues and bond issues each year in proportion to debt-equity financing employed.
5. Effective income tax rate is constant over the course of the project.

Several different procedures for calculating an annualized (or levelized) revenue requirement are demonstrated in example 2. All produce identical results and clarify the basic assumptions that underlie this method of economic evaluation. Example 2 is further utilized in Sect. 3 to show that the PW and the RR methods are comparable and consistent figures of merit for economic decision making.

A new piece of equipment being installed by an electrical utility company has an investment cost of $84,000 and a tax life of four years. For purposes of simplifying this example, tax life and book life of the equipment are considered the same. In addition, the salvage value of the equipment is negligible. Annual operating and maintenance (O&M) costs are expected to be $30,000, and the utility's tax-adjusted average cost of capital (i') is 12%. Furthermore, the effective income tax rate is 50%, and debt capital (bonds) costs 8% per year. The fraction of total capitalization represented by debt is 0.25. Finally, annual revenues are expected to be $67,000, but this will be ignored initially because the RR method does not formally require this information.

The tax-adjusted *minimum* rate of return (i') that is acceptable to the utility company is determined with this equation:*

$$i' = f_E R_E + (1 - t_e)\ f_D R_D\ , \tag{10}$$

where

f_E = fraction of equity capital (owner's equity),
R_E = rate of return on equity capital,
f_D = fraction of debt capital (bonds),
R_D = rate of return on debt capital,
t_e = effective income tax rate.

If $i' = 0.12$, it can be determined from the data given above and Eq. (10) that $R_E = 0.1467$ when $R_D = 0.08$.

To determine the annual carrying charges in year n as a *fraction* of unrecovered investment for this piece of equipment, Eq. (11) is utilized:[5]

$$CC = D_B + f_E R_E + f_D R_D + T\ , \tag{11}$$

where

D_B = book depreciation,
T = income taxes.

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*There is some controversy over whether an investor-owned utility should use a tax-adjusted or a non-tax-adjusted minimum rate of return (here synonymous with the average cost of capital) in its determination of present worth of revenue requirements. J. B. Oso provides a proof that the tax-adjusted cost of capital is the only discount rate that equates revenue streams, capital obligations, and operating expenses to the same value (see ref. 3). Appendix B also provides support for using the tax-adjusted average cost of capital for discounting annual revenue requirements. On the other hand, many agencies and utilities recommend using the nonadjusted cost of capital, $i^* = f_E R_E + f_D R_D$, based primarily on the work of Jeynes (see ref. 2). One such agency is the Electric Power Research Institute (see ref. 4).

With an effective income tax rate (t_e) of 50%, income taxes are equal to 50% of the before-tax net income remaining after allowable deductions are subtracted from operating revenues. However, tax depreciation and interest paid to bondholders are components of carrying charges that are tax deductible. To determine income taxes as an element of carrying charges, Eq. (12) applies when all quantities are expressed as a fraction of the unrecovered investment in any given year:

$$T = t_e(CC - f_D R_D - D_T) \ , \tag{12}$$

where

D_T = tax depreciation.

There are now two equations, (11) and (12), expressed in two unknowns, CC and T. After solving them simultaneously, the following expression for T is obtained:

$$T = \frac{t_e}{1 - t_e} (f_E R_E + D_B - D_t) \ . \tag{13}$$

In this example problem, suppose that straight-line depreciation is used for book and tax purposes, that is, $D_B = D_t$. The annual depreciation rate in year 1 is 21,000/84,000 = 0.25, $f_E R_E$ is 0.11, and $f_D R_D$ is 0.02. Now the annual carrying charge as a fraction of unrecovered investment in year 1 can be computed by using Eqs. (11) and (13):

$$\begin{aligned} CC_1 &= 0.25 + 0.11 + 0.02 + 0.11 \\ &= 0.49 \text{ of unrecovered investment.} \end{aligned}$$

The carrying charge for the first year in its equivalent annual dollar amount is then 0.49($84,000) = $41,160. The revenue requirement for this piece of equipment during the first year is determined with Eq. (9):

$$\begin{aligned} \text{year 1 RR} &= \$41,160 + \text{all associated expenses} \\ &= \$41,160 + \$30,000 \\ &= \underline{\$71,160}. \end{aligned}$$

Carrying charges and the revenue requirement in years 2, 3, and 4 are calculated in the following manner:

Year	Carrying charge as a fraction of unrecovered investment
2	21,000/63,000 + 0.11 + 0.02 + 0.11 = 0.5733
3	21,000/42,000 + 0.11 + 0.02 + 0.11 = 0.7400
4	21,000/21,000 + 0.11 + 0.02 + 0.11 = 1.2400

Year	Revenue requirement
2	0.5733($63,000) + $30,000 = $66,120
3	0.7400(42,000) + 30,000 = $61,080
4	1.2400(21,000) + 30,000 = $56,040

To obtain an RR that is a *levelized equivalent* of the values above, the tax-adjusted average cost of capital (i′) for the utility is utilized:

$$\text{levelized revenue requirement} = \overline{RR} = [\$71{,}160\ (P/F,\ 12\%,\ 1) + \$66{,}120\ (P/F,\ 12\%,\ 2) + \$61{,}080\ (P/F,\ 12\%,\ 3) + \$56{,}040\ (P/F,\ 12\%,\ 4)]\ (A/P,\ 12\%,\ 4) = \underline{\$64{,}311}\ .$$

The capital recovery factor (A/P, i′%, N) is widely used in engineering economic studies and is further discussed in Appendix C.

The process of leveling year-by-year RR to arrive at a uniform annual amount that can be used for decision-making purposes is graphically portrayed in Fig. 6 and is described in books dealing with the subject of engineering economics.[6]

The levelized revenue requirement ($\overline{RR}$) of $64,311 is the *minimum* RR shown in Fig. 4. Recall from the original problem statement that expected annual revenue attributable to the equipment is $67,000. Consequently, $\overline{RR}$ is exceeded by $2689, which means that the new equipment offers a prospective "profit" of $1344.50 matched by a $1344.50 tax liability (see Fig. 4), since the effective income tax rate is 0.50. Hence the equipment appears to be a good investment.

A second popular approach for calculating annual revenue requirements is to construct a table in which all dollar components of the revenue requirement are directly determined. Such a table is highly

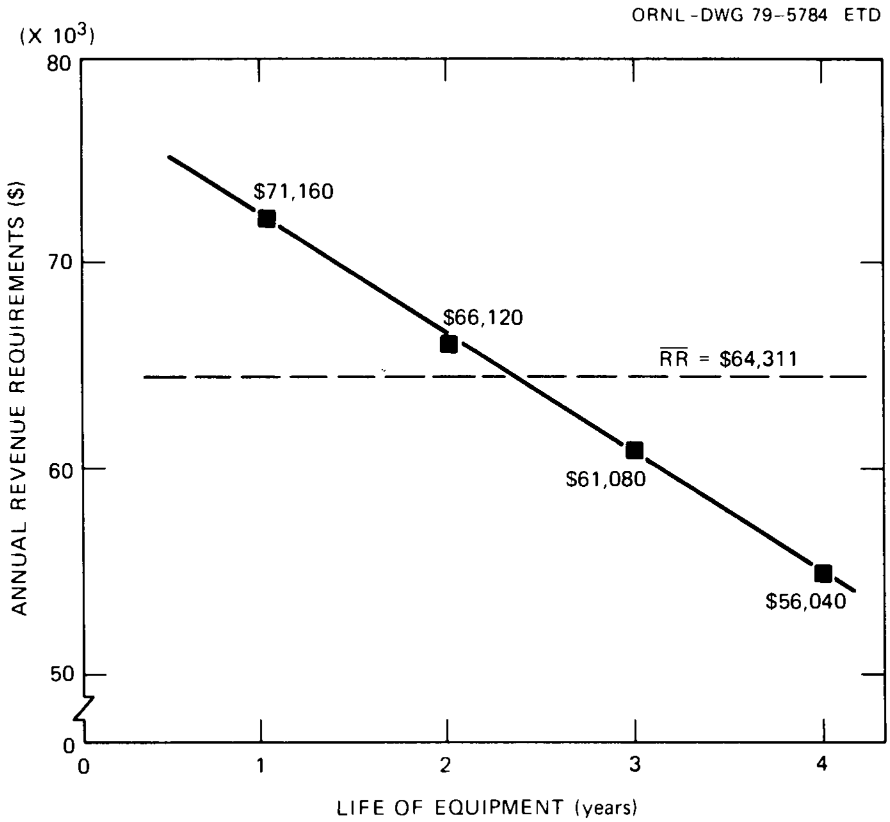

Fig. 6. Relationship between annual revenue requirements and the levelized revenue requirement ($\overline{RR}$).

useful when including the effects of inflation and other complications (to be demonstrated later). This second approach to determining the $\overline{RR}$ of example 2 directly expresses the dollar equivalents of Eqs. (9–13) in Table 5, where tax and book depreciation are again equal. The levelized RR at the firm's tax-adjusted minimum rate of return (12%) is determined from Table 5, and the same results are obtained:

$$\overline{RR} = \underline{\$64,311} \ .$$

Example 2 can be used to indicate why discounting of annual revenue requirements, which are calculated with Eqs. (9–13), should be performed at i′ = 12% from Eq. (10) rather than at the non-tax-adjusted weighted cost of capital, i* = 13%. To show why this is intuitively true, Tables 6 and 7 have been prepared. Table 6 illustrates how revenue requirements

Table 5. Annual revenue requirement for new equipment

Year	(1) Unrecovered investment	(2) Depreciation	(3) O&M	(4) Debt return 0.25(0.08) × (Col. 1)	(5) Equity return 0.75(0.1467) × (Col. 1)	(6) Income taxes T = Col. 5[a]	(7)[b] RR = Cols. 2 + 3 + 4 + 5 + 6
1	\$84,000	\$21,000	\$30,000	\$1680	\$9240	\$9240	\$71,160
2	63,000	21,000	30,000	1260	6930	6930	66,120
3	42,000	21,000	30,000	840	4620	4620	61,080
4	21,000	21,000	30,000	420	2310	2310	56,040

[a] T = Col. 5 only when $t_e = 0.50$. When $t_e \neq 0.50$, Eq. (13) is applicable.

[b] Present worth of Col. 7 at i′ of 12% = \$195,339.

Table 6. Year-by-year revenue requirements expressed in terms of unknown income taxes (f_D = 0.25, R_D = 0.08, t_e = 0.50)

Year	(1) Required earnings to cover fair return,[a] depreciation, income taxes	(2) Depreciation deduction from taxable income	(3) Interest expense after income taxes	(4) Taxable income (TI) (4) = (1) − (2) − (3)	(5) Income tax, T_i[b] T_i = 0.5(TI)	(6) Revenue requirement[c] = fair return + depreciation + income taxes + tax credit due to interest + O&M
1	0.12(84,000) + 21,000 + T_1	21,000	0.25(1 − 0.5)(0.08)(84,000) = 840	9240 + T_1	9240	71,160
2	0.12(63,000) + 21,000 + T_2	21,000	0.01(63,000) = 630	6930 + T_2	6930	66,120
3	0.12(42,000) + 21,000 + T_3	21,000	0.01(42,000) = 420	4620 + T_3	4620	61,080
4	0.12(21,000) + 21,000 + T_4	21,000	0.01(21,000) = 210	2310 + T_4	2310	56,040

[a] Fair return on investment is assumed to equal after-tax weighted cost of capital, i′ = 12%, multiplied by the beginning-of-year book value of the asset.

[b] T_i in year 1 = 0.5(9240 + T_1), or $T_1/2$ = 1/2(9240), so T_1 = \$9240.

[c] Revenue requirement in year 1 = 0.12(84,000) + 21,000 + 9240 + 840 + 30,000 = \$71,160. O&M is \$30,000 per year. The present worth of column 6 is \$195,339 at i′ = 12%.

Table 7. Year-by-year revenue requirements expressed in terms of unknown income taxes (f_D = 0.25, R_D = 0.08, t_e = 0.50)

Year	(1) Required earnings to cover fair return,[a] depreciation, income taxes	(2) Depreciation deduction from taxable income	(3) Before-tax cost of interest	(4) Taxable income (TI) (4) = (1) − (2) − (3)	(5) Income tax, T_i[b] T_i = 0.5(TI)	(6) Revenue requirement[c] = fair return + depreciation + income taxes + O&M
1	0.13(84,000) + 21,000 + T_1	21,000	(0.25)(0.08)(84,000) = 1680	9240 + T_1	9240	71,160
2	0.13(63,000) + 21,000 + T_2	21,000	1260	6930 + T_2	6930	66,120
3	0.13(42,000) + 21,000 + T_3	21,000	840	4620 + T_3	4620	61,080
4	0.13(21,000) + 21,000 + T_4	21,000	420	2310 + T_4	2310	56,040

[a]Fair return on investment is assumed here to equal the nontax adjusted weighted cost of capital, i* = (8.0%)(0.25) + (14.67%)(0.75) = 13%.

[b]For example, T_1 = 0.5(9240 + T_1), or T_1 = 9240.

[c]Revenue requirement in year 1 = 0.13(84,000) + 21,000 + 9240 + 30,000 = $71,160. O&M is $30,000 per year. Because column 4 understates taxable income by the before-tax cost of interest, column 5 includes a credit against income taxes due to interest. The before-tax cost of interest is integral to column 1, since i* contains a term for the full interest expense ($f_D \cdot R_D$). Thus the after-tax cost of interest is carried directly to column 6 in terms of "fair return + income taxes." As a result, discounting should occur at i′ = 12%. If column 6 were discounted at i* = 13%, the present worth of revenue requirements would be $191,459, which is 2% less than the present worth calculated at 12%.

are determined without direct use of Eqs. (11—13). This table indicates how income taxes can be treated as an unknown when i' is utilized to compute the "fair return" on capital investment and, subsequently, the revenue requirement in column 6. Notice that the fair return in column 1 of Table 6 includes only the after-tax cost of interest, which is then deducted in column 4 to arrive at the taxable income. Income taxes in column 5 are then equal to return on equity when $t_e = 0.5$. Finally, column 6 has added back to it the tax credit due to interest so that the entire interest expense is included in the annual revenue requirement (but only after the after-tax cost of interest has been incorporated into column 5).

Equations (12) and (13) represent a shortcut method for determining income taxes that reflect deductions attributable to interest and tax depreciation in a revenue requirement analysis. The procedure for computing annual revenue requirements in terms of unknown income taxes has been explicitly demonstrated in Table 6. Results of Tables 5 and 6 are identical, and discounting should be at i' because only the after-tax cost of interest [i.e, $(1 - t_e) \times f_D \times R_D$] is reflected in column 5. That is, Eq. (12) includes the tax credit due to interest as $t_e(f_D R_D)$. The after-tax cost of interest is thus $(1 - t_e)(f_D R_D)$, which is included in the carrying charges upon combining Eqs. (11) and (12). This perspective is normally taken by the managers of an investor-owned utility, since they are concerned with the after-tax cost of capital to the firm. Such an approach might also be termed the "treasurer's point of view."

This same problem can be reworked from the viewpoint of the "outside investor" in a utility who is not in a position to take advantage of the tax credit on interest as debt capital is used by the firm. He sees the cost of money before taxes as relevant, so is inclined to judge a "fair return" in terms of i^*. Table 7 indicates how Table 6 is reworked when a fair return of $i^* = 13\%$ (i.e., the overall cost of capital) is incorporated into column 1. Column 3 now contains the annual *before-tax* cost of borrowed funds. The tax credit arising from interest expense is still reflected in column 5 of Table 7, and this column is numerically the same as column 5 of Table 6. Now column 6 has included in it the before-tax cost of interest, since it was initially contained in the fair return of column 1. Thus, no interest adjustments need to be made in column 6 of Table 7 to incorporate the full amount of the interest expense in the annual revenue requirement. In both tables the annual revenue requirements are identical.

If a "utility management" perspective is taken, the revenue requirements in Table 7 should be discounted at $i' = 12\%$. It is shown in this report that the utility management perspective is equivalent to the stockholder's viewpoint that is implicitly taken in most present-worth analyses conducted by nonregulated firms. For this reason, i' is used to discount revenue requirements throughout the report and is recommended as the discount rate to use in demonstrating equivalence between the RR and PW methods. Additional discussion of different perspectives taken in engineering economic evaluations is given later.

4. EQUIVALENCE OF THE RR METHOD AND THE PW METHOD

4.1 Use of Example 2 to Establish Equivalence

It is possible to demonstrate the equivalence of the RR method and the PW method through various approaches covered in this section. Example 2 serves as a vehicle for calculations to follow. However, it must be stressed that conditions underlying the application of each economic evaluation method are identical.

Probably the most straightforward procedure for establishing equivalence of the methods is to construct a table similar to Table 2 in which the after-tax cash flow is calculated in terms of an unknown, uniform annual revenue (R). This revenue is a levelized RR by definition and is determined such that the present worth of annual revenues exactly equals the present worth of all disbursements, including income taxes, over the project's duration. Hence a present-worth analysis is performed for example 2 so that R can be compared with the $\overline{\overline{RR}}$ calculated in the previous section.

The interest rate to be utilized in establishing this equality in present worth is the return on equity (R_E) — not the tax-adjusted minimum rate of return (i') used with the RR method. In the PW method it is assumed that R_E at least equals the tax-adjusted cost of capital to the firm. In actual practice, R_E in nonregulated firms usually is greater than R_E in utilities because the riskiness of investments is greater.

The format shown in Table 8 for determining year-by-year after-tax cash flow is based on Table 2 and indicates the necessary steps to calculate R (the levelized revenue requirement as determined by the PW method). It can be seen that when R = \$64,420, the present worth of cash outflows (disbursements) equals the present worth of cash inflows (revenues) at a discount rate of R_E = 14.67%. This is quite close to the $\overline{\overline{RR}}$ of \$64,311 determined in Sect. 3 (rounding interest factors to four decimal places accounts for most of the discrepancy). The error is about 0.2%, which is the amount that the RR method consistently underestimates R as calculated in Table 8 by the PW method for example 2. This level of error also applies to results when different debt-equity balances are considered as

Table 8. Present-worth analysis of example 2 to solve for levelized RR at which R_E is achieved (f_E = 0.75 and i′ = 12%)

Year	Operating revenues (years 1–4), capital investment (year 0)	Loan cash flow		Before-tax cash flow (investment in year 0)	Depreciation $D_B = D_T$	Taxable income	Income taxes	After-tax cash flow (investment in year 0)
		Principal	Interest					
0	−84,000	+21,000		−63,000				−63,000
1	R − 30,000	−5,250	−1680	R − 31,680	−21,000	R − 52,680	−0.5R + 26,340	0.5R − 10,590[a]
2	R − 30,000	−5,250	−1260	R − 31,260	−21,000	R − 52,260	−0.5R + 26,130	0.5R − 10,380
3	R − 30,000	−5,250	−840	R − 30,840	−21,000	R − 51,840	−0.5R + 25,920	0.5R − 10,170
4	R − 30,000	−5,250	−420	R − 30,420	−21,000	R − 51,420	−0.5R + 25,710	0.5R − 9,960

[a]For example, 0.5R − 10,590 = (R − 31,680) − 0.5R + 26,340 − 5250.

When R_E = 0.1467, 63,000 = (0.5R − 10,590)(P/F, 14.67%, 1) + (0.5R − 10,380)(P/F, 14.67%, 2) + (0.5R − 10,170)(P/F, 14.67%, 3) + (0.5R − 9960)(P/F, 14.67%, 4),

$$\text{or } R = \frac{63{,}000 + 29{,}636}{1.438} = \underline{\$64{,}420}.$$

well as values of t_e other than 0.5 (results of these analyses are not given here).

Another approach to demonstrating equivalence of the two methods is to perform a present-worth analysis in which the computed rate of return on equity capital is determined from the annual RR developed with Eqs. (9–13) (see Table 5). If this computed internal rate of return is identical to R_E, the two methods yield the same results and are equivalent. The after-tax cash flow analysis corresponding to this approach is presented in Table 9. The internal rate of return on after-tax cash flow is determined by solving for the interest rate at which cash outflow equals cash inflow:

$$\$63{,}000 = \$24{,}990\ (P/A,\ IRR,\ 4) - \$2310\ (P/G,\ IRR,\ 4),$$

or by trial and error,

$$IRR = 14.67\%\ (= R_E)\ .$$

In a similar fashion, example 2 could have been worked by omitting the revenue requirement (R) from before-tax cash flows (BTCF) in Table 8 and determining the present worth of negative-valued after-tax cash flows (ATCF) at R_E. Then the levelized revenue requirement in Sect. 3 can be directly computed from the resulting present worth of costs as follows:

$$\overline{RR} \cong \frac{-\,(\text{PW of costs at } R_E)(A/P,\ R_E,\ 4)}{1 - t_e}\ . \tag{14}$$

The validity of Eq. (14) is apparent after referring to Table 8, where the following relationship is utilized with $t_e = 0.50$:

$$63{,}000 + \text{PW of after-tax costs at } 14.67\% = \text{PW of } 0.5R \text{ at } 14.67\%\ .$$

Another way of stating this relationship is:

$$(\text{PW of after-tax costs at } 14.67\%)(\text{capital recovery factor at } 14.67\%) = 0.5R\ .$$

Table 9. Internal rate-of-return analysis on equity capital in example 2

Year	Operating revenues[a] (years 1–4), capital investment (year 0)	Loan cash flow		Before-tax cash flow (investment in year 0)	Depreciation $D_B = D_T$	Taxable income	Income taxes	After-tax cash flow (investment in year 0)
		Principal	Interest[b]					
0	−$84,000	+$21,000		−$63,000				−$63,000
1	(71,160 − 30,000)	−5,250	−$1680	−39,480	−$21,000	$18,480	−$9240	24,990
2	(66,120 − 30,000)	−5,250	−1260	−34,860	−21,000	13,860	−6930	22,680
3	(61,080 − 30,000)	−5,250	−840	−30,240	−21,000	9,240	−4620	20,370
4	(56,040 − 30,000)	−5,250	−420	−25,620	−21,000	4,620	−2310	18,060

[a] Includes the year-by-year revenue requirement calculated in Table 5.

[b] Twenty-five percent of $84,000 is borrowed at 8% interest.

In general terms, this becomes the following:

$$\frac{(\text{PW of after-tax costs at } R_E)(A/P,\ R_E,\ N)}{1 - t_e} = R\ .$$

The value of R above is a close approximation of $\overline{RR}$ as it was determined in Sect. 3.

To illustrate how this works, the problem is resolved after considering only costs in the BTCF column of Table 8. The results are given in Table 10. The present worth of the ATCF column at R_E = 14.67% is —\$92,635, and the uniform annual equivalent cost at 14.67% is —\$32,231. From Eq. (14) the $\overline{RR}$ is \$32,231/(1 — 0.5) = \$64,462. The corresponding value from Table 8 is \$64,420.

This result agrees quite closely with the previous estimate of \$64,311 obtained from Table 5 by "building up" the annual RR from component costs and then levelizing them with the tax-adjusted average cost of capital (i′). Thus, for example 2 it has been demonstrated that the RR method and the PW method, based solely on costs, produce the same results if underlying assumptions are identical. Consequently, it is a simple matter to convert results of one method to those of the other if the conditions of the analysis are identical and used consistently. A set of equations for accomplishing this has been developed and is included in Appendix D.

Note that with the RR method, levelizing is accomplished at the firm's tax-adjusted average cost of capital. On the other hand, discounted cash flow analysis with the PW method utilizes R_E, which is the return on equity. This difference in discounting rates arises because of the manner in which debt and equity financing is treated with each method and the *perspective* taken in the analysis. Differences in perspective (i.e., stockholders' interests, the firm's interests, and the investors' viewpoint) are discussed later in this section.

If the debt-equity balance in example 2 is varied, the equivalence of the two methods of economic analysis is *unaffected*. Up to this point, example 2 has been worked with 25% debt financing and 75% equity financing. Results of further investigation of the levelized revenue requirement, as

Table 10. Present-worth analysis based only on costs associated with example 2

Year	Operating revenues (years 1–4) capital investment (year 0)	Loan cash flow		Before-tax cash flow (investment in year 0)	Depreciation	Taxable income	Income taxes	After-tax cash flow (investment in year 0)
		Principal	Interest					
0	–$84,000	+$21,000		–$63,000				–$63,000
1	–30,000	–5,250	–1680	–31,680	–$21,000	–$52,680	+$26,340	–10,590
2	–30,000	–5,250	–1260	–31,260	–21,000	–52,260	+26,130	–10,380
3	–30,000	–5,250	–840	–30,840	–21,000	–51,840	+25,920	–10,170
4	–30,000	–5,250	–420	–30,420	–21,000	–51,420	+25,710	–9,960

it varies with the debt-equity ratio, are given in Table 11. Here it is clear that both methods provide equivalent results when the appropriate discount rates are used. Furthermore, Fig. 7 portrays a linear relationship between the revenue requirement and the proportion of the investment financed by borrowed funds (debt capital).

Table 11. Results of selected combinations of debt-equity balances upon the levelized revenue requirement of example 2

Financing plan	RR method [Eqs. (9–13)]	Revenue requirement estimated with Eq. (14)
100% equity	$67,451	$67,456
75% equity, 25% debt	64,311	64,420
50% equity, 50% debt	61,246	61,430
25% equity, 75% debt	58,227	58,440
100% debt	55,284	55,451

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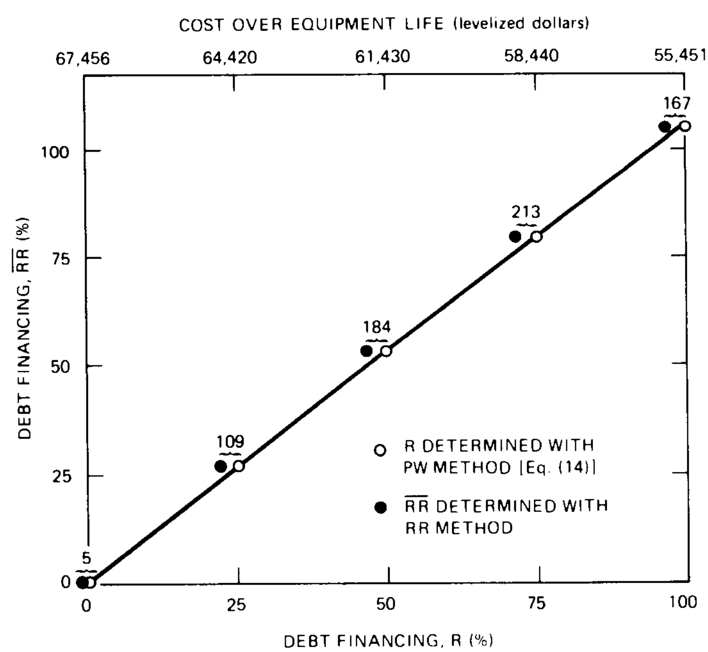

Fig. 7. Graphical summary of a linear relationship between $\overline{RR}$ and percent debt financing.

4.2 Effect of Differences in Perspective on Example 2

When assumptions that underlie the PW and the RR method are not identical, results of analyses such as the foregoing will obviously be affected. Important assumptions of the PW method are listed on p. 7 and those underlying the RR method are given on p. 28.

The perspective taken in solving problems by either the PW or RR method is of critical importance to identifying common assumptions underlying these methods of economic evaluation. In example 2 (Sect. 3) it was shown that the position of stockholders, which is often taken in PW studies, is equivalent to the viewpoint of the management of a utility as it conducts economic evaluations by using the RR method. These two viewpoints are frequently presented in the literature with little explanation of *which* viewpoint has been taken or *why* a particular perspective was incorporated into the analysis.

It is interesting to note that other perspectives could have been taken in example 2 and that equivalence among them could also have been demonstrated. In the discussion that follows, the two most popular viewpoints previously covered in example 2 are shown to be equivalent *to two other perspectives* that could have been taken (C and D below):

Perspectives taken in example 2	Additional perspectives discussed here
A. Stockholder (discounting occurs at R_E as done in PW method	C. Bondholder (discounting occurs at R_D
B. Utility management (discounting occurs at i′ as often done in RR method)	D. Outside investor (discounting occurs at $i^* = f_E R_E + f_D R_D$)

In RR studies, there is often disagreement regarding which discount rate is appropriate — the tax-adjusted weighted cost of capital (i′ in perspective B) or the unadjusted weighted cost of capital (i* in perspective D). As shown earlier in Sect. 3, this issue is really one of *whose viewpoint* should be reflected in the economic evaluation of projects.

To demonstrate that all four perspectives lead to equivalent and consistent results, the notation below is first presented for year n in the life of a project:

G = operating revenues,

E = cash expenses other than interest expense,

D = depreciation (book = tax), which is return *of* investment (see Fig. 2),

$D = f_E D + f_D D$ (f_E is fraction equity in total capitalization and f_D is fraction debt in total capitalization),

I = interest expense (= return *on* debt),

$f_E R_E$ = net income after taxes (see Fig. 2), where R_E is the rate of return *on* equity,

T = income tax expense, where $T = t_e(G - E - I - D)$.

From Eq. (4) it can be seen that net income after taxes is

$$f_E R_E = (G - E - D - I)(1 - t_e) \ ,$$

and after rearranging terms, net income, which equals return on equity as shown in Fig. 2, becomes

Tax credits due to depreciation and interest respectively

$$\underbrace{f_E R_E}_{\text{Return on equity}} = (G - E)(1 - t_e) + t_e D - \underbrace{f_D D}_{\text{Return of debt capital}} - \underbrace{f_E D}_{\text{Return of equity capital}} - \underbrace{I}_{\text{Return on debt}} + It_e \ . \tag{15}$$

The basic equation can be written in four ways to express perspectives A–D given above. Perspective A places $f_E R_E + f_E D$ on the left side of the equality to provide a basis for calculating a rate of return on equity capital (i.e., the stockholder's viewpoint). In example 2, the \$63,000 equity portion of the investment must equal the present worth at R_E of annual return *on* equity ($f_E R_E$) and annual return *of* stockholders' capital ($f_E D$) as follows (refer to Table 5):

Year	$f_E R_E + f_E D$ (in dollars)	
1	9240 + 15,750	PW at R_E = \$63,000
2	6930 + 15,750	
3	4620 + 15,750	
4	2310 + 15,750	

$$\$63{,}000 = \$24{,}990\ (P/F,\ 14.67\%,\ 1) + \$22{,}680\ (P/F,\ 14.67\%,\ 2) + \$20{,}370\ (P/F,\ 14.67\%,\ 3) + \$18{,}060\ (P/F,\ 14.67\%,\ 4)$$

or

$$\$63{,}000 = \$63{,}000$$

Perspective B is equivalent to perspective A by placing annual after-tax return on equity, after-tax cost of interest, and return of investment on the left side of Eq. (15). The resultant rate of return calculated on the \$84,000 investment is the tax-adjusted weighted cost of capital, i':

Year	$D + I(1 - t_e) + f_E R_E$ (in dollars)
1	21,000 + 840 + 9240
2	21,000 + 630 + 6930
3	21,000 + 420 + 4620
4	21,000 + 210 + 2310

$$\$84{,}000 = \$31{,}080\ (P/F,\ 12\%,\ 1) + \$28{,}560\ (P/F,\ 12\%,\ 2) + \$26{,}040\ (P/F,\ 12\%,\ 3) + \$23{,}520\ (P/F,\ 12\%,\ 4)$$

or

$$\$84{,}000 = \$84{,}000$$

In summary, the above difference in analytical perspective for example 2 explains the equivalence of the PW method (perspective A) and the RR method (perspective B), where two different discount rates are involved. Perspective C could also be utilized to calculate a rate of return from the bondholders' viewpoint, although this approach to economic evaluation is not in widespread use. Finally, perspective D represents the viewpoint of an "outside investor" in an investor-owned utility. This is similar to perspective B except that before-tax cost of interest (I) is substituted for the after-tax cost of interest, and the discount rate that establishes equivalence is i*. An overview of all four analytical viewpoints is given in Table 12.

A set of generalized equations for the common case where $t_e = 0.50$ has been developed in Appendix D to enable one to "translate" results of a present-worth analysis into corresponding results in a revenue requirement study and vice versa. By using these equations for example problems in this report, the equivalence of both methods of economic evaluation can be further demonstrated.

Table 12. Different perspectives for evaluating engineering economics problems

	A	B	C	D
Description	Stockholder	Utility management	Bondholder	Outside investor
Investment in year 0 on which a return is desired	$f_E \times \$84,000 = \$63,000$	$84,000	$f_D \times \$84,000 = \$21,000$	$84,000
Required dollar return in years 1–4	$f_E D + f_E R_E$	$D + I(1 - t_e) + f_E R_E$	$f_D D + I$	$D + I + f_E R_E$
1	$24,990	$31,080	$6930	$31,920
2	22,680	28,560	6510	29,190
3	20,370	26,040	6090	26,460
4	18,060	23,520	5670	23,730
Rate of return on investment	14.67%	12.00%	8.00%	13.00%

5. ANALYSIS OF MULTIPLE ALTERNATIVES

5.1 Introduction

In this section the objective is to compare two mutually exclusive alternatives with the economic evaluation procedures described previously. One of the alternatives is capital intensive, while the other incurs higher annual costs relative to the first and less capital investment. When evaluating alternatives with the PW method, the perspective of the *owners* (i.e., stockholders) of a competitive firm is taken. This is perspective A from the previous section. The owners of such a firm are concerned with maximizing wealth through increasing the productivity of invested capital. On the other hand, with the RR method the viewpoint of the *customers* of a regulated utility company is usually taken. That is, the practice of minimizing the revenue requirement when selecting among competing alternatives will be a governing factor in the decision process and protects customers' interests in utilities that are monopolistic in character. This is reflected in perspective B of the previous section, although perspective D is often taken in revenue requirement studies.

To illustrate the analysis of multiple alternatives in addition to important differences between competitive and regulated industry perspectives, suppose the decision to be made concerns whether to purchase the new piece of equipment in example 2 or to retain the present equipment. Specifically, the alternative to purchasing new equipment is to upgrade the existing equipment at a cost of $20,000. Present book value of the existing equipment is zero, and, if upgraded, its salvage value in four years is expected to be negligible. After upgrading the equipment, the O&M costs will be $50,000 per year. All other conditions given earlier still apply.

Since multiple alternatives (two or more) are often analyzed two at a time, as indicated in Fig. 8, the two alternatives described above will satisfactorily demonstrate fundamentals of the pairwise evaluation procedure. A brief summary of data relevant to each alternative is given below:

	New equipment	Upgraded existing equipment
Capital investment	\$84,000	\$20,000
Annual O&M	\$30,000	\$50,000
Salvage value	-0-	-0-
Expected life	4 years	4 years
Annual revenues	\$67,000	\$67,000

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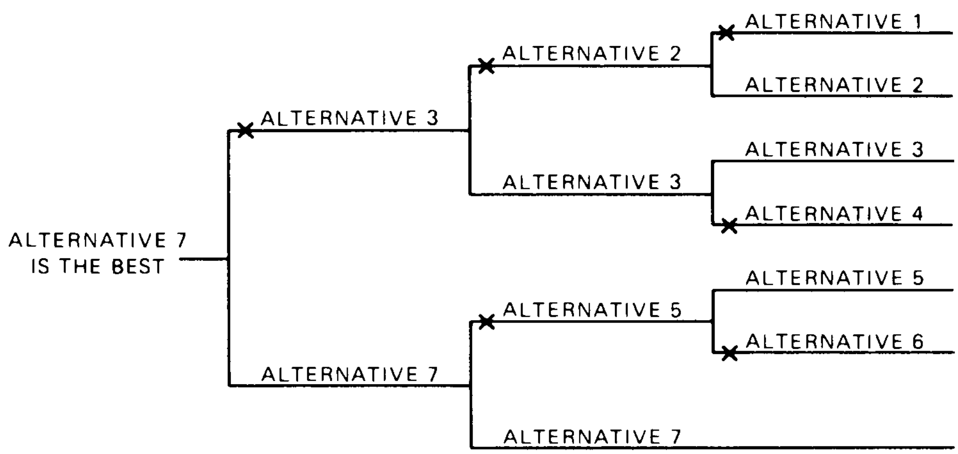
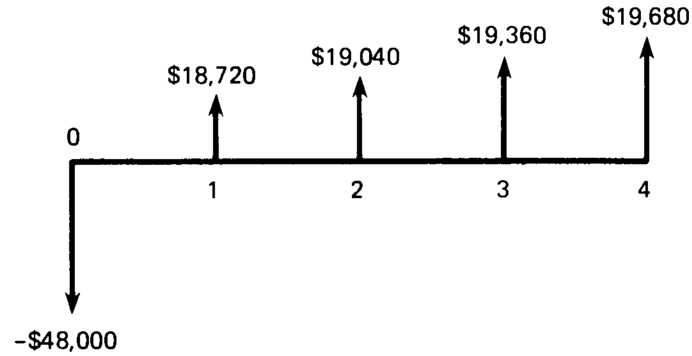


Fig. 8. Pairwise comparison of seven mutually exclusive alternatives.

5.2 Analysis by the Present-Worth Method (Nonregulated Firm)

When considered two at a time, cash flow differences between mutually exclusive alternatives summarize the trade-offs relevant to the decision-making process. Apart from income tax considerations, trade-offs present in the example are shown below in terms of incremental cash flows:

New equipment (upgraded existing equipment)



These incremental cash flows are calculated from the "BTCF" column of Table 13.

If straight-line depreciation is used by this private sector, competitive firm, the annual write-off is $16,000 more for the new equipment relative to upgrading existing equipment (see Table 13). This offsets taxable income for the more capital intensive alternative and increases ATCF by 0.5($16,000) = $8000 relative to upgrading existing equipment. This advantage is partially offset by the extra repayments of debt principal that must be made when purchasing new equipment in addition to larger interest payments each year. The ATCF for each alternative is indicated in Table 13 and summarized below:

After-tax difference (new equipment — upgraded equipment)

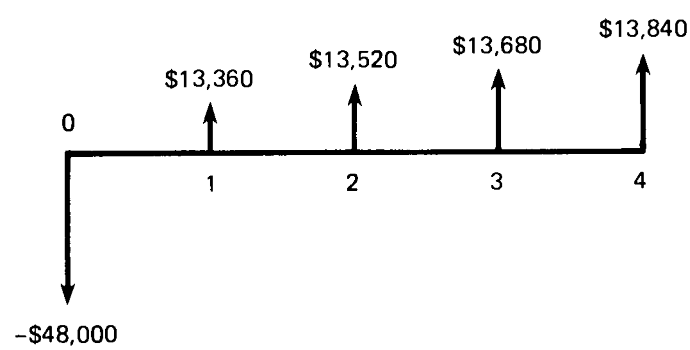


Table 13. After-tax cash flow analysis of two alternatives for providing the same service

Year	Before-tax cash flow	Depreciation	Taxable income	Income taxes, $t_e = 0.50$	After-tax cash flow
	I. New equipment, 75% equity, 25% debt, $R_E = 0.1467$, $R_D = 0.08$, revenue = \$67,000/year				
0	−\$63,000				−\$63,000
1	35,320[a]	−\$21,000	\$14,320	−\$7160	+22,910
2	35,740	−21,000	14,740	−7370	+23,120
3	36,160	−21,000	15,160	−7580	+23,330
4	36,580	−21,000	15,580	−7790	+23,540
	II. Upgraded equipment, 75% equity, 25% debt, $R_E = 0.1467$, $R_D = 0.08$, revenue = \$67,000/year				
0	−\$15,000				−\$15,000
1	16,000[b]	−5,000	11,600	−5800	+9,550[c]
2	16,700	−5,000	11,700	−5850	+9,600
3	16,800	−5,000	11,800	−5900	+9,650
4	16,900	−5,000	11,900	−5950	+9,700

[a]Referring to the BTCF column of Table 10, this entry equals \$67,000 − \$31,680.

[b]This entry, for example, is calculated as follows:

\$67,000	−	\$50,000	− \$20,000(0.25)(0.08)
(projected revenues)		(O&M)	(interest on debt)

[c]This entry takes into account repayment of loan principal in the amount of \$5000/4 = \$1250 per year: \$16,600 − 5800 − 1250 = \$9550.

Because the return to equity is 14.67% in this problem, the present worth of each alternative's ATCF is determined to be

new equipment, net PW(14.67%) = +\$3651 ,

upgraded equipment, net PW(14.67%) = +\$12,640

To maximize present worth, the upgraded equipment should be selected. Here the perspective is that of owners of the firm. Notice that the analysis in Table 13 included the projected revenue attributable to this function, which either alternative can satisfy equally well. In contrast, the RR method aims at minimizing revenue that must be generated to cover incremental costs of each alternative and does consider "profits" and taxes on profits when applicable.

5.3 Analysis by the Revenue Requirement Method (Regulated Firm)

The same two alternatives are now evaluated with the RR method. From Table 5 the levelized RR was computed to be \$64,311 for the new machine. Because \$64,311 is less than \$67,000 (projected revenue), it was concluded that new equipment is economically attractive to the utility.

By again using Eqs. (9–13), the annual revenue requirement associated with upgrading the equipment can be determined to equal the following:

Year	Revenue requirement	$\overline{RR}$ at $i' = 12\%$
1	\$59,800	
2	\$58,600	\$58,168
3	\$57,400	
4	\$56,200	

The alternative recommended would be to upgrade the existing machine because \$58,168 is less than \$64,311.

5.4 An Illustration of Reversal in Preference Orderings

In the absence of complicating factors, present-worth analysis results in the same preferred alternative as does the RR method. This is shown in Table 14 when revenues of \$67,000 per year are included and also when only costs are considered. Both the PW and the RR method produce consistent results as evidenced by the constant ratio of evaluation criteria. However, because of differences in the way competitive and regulated firms operate, it is possible (but not highly likely) for the two methods to yield contrasting results when certain economic conditions exist.

To demonstrate a reversal in preference of the two previous alternatives due to changing economic conditions, suppose that the decision has been made to upgrade existing equipment and that inflation *increases* 20% each year over and above the O&M estimates initially prepared. The competitive firm would compensate for this by increasing its prices and, hence, revenues by 20% annually. In this situation the *upgraded* equipment is still the most economical choice.

Table 14. Summary of comparison between two alternatives

75% equity, R_E = 14.67%; 25% debt, R_D = 8.00%
revenue = \$67,000/year, straight-line depreciation, uniform repayment of borrowed capital, life = 4 years, t_e = 0.50

	(A) New equipment	(B) Existing equipment
Present worth at 14.67% (including revenues)	+\$3,651	+\$12,640
Present worth at 14.67% (costs only)	−92,636	−83,646
Revenue requirement at 12.00%	64,311	58,168

Ratios for consistency check

$$\frac{(PW - C)_B}{(PW - C)_A} = \frac{-83{,}646}{-92{,}636} = 0.903 \qquad \frac{\overline{RR}_B}{\overline{RR}_A} = \frac{58{,}168}{64{,}311} = 0.904$$

In contrast, this situation presents some difficulties for the regulated utility just completing a hearing at which a rate hike had *not* been approved. A 20% increase in O&M costs raises the $\overline{RR}$ for the new equipment to roughly \$81,500, and the $\overline{RR}$ for the upgraded equipment increases to about \$86,500. Neither option is financially attractive, but the revenue requirement is now minimized for the option of purchasing the new equipment. If no other choices were available, this selection would minimize the losses that the utility might expect until another rate hearing was held. Additionally, in view of the unanticipated cost increases, the utility may elect to purchase the equipment, since its expected service life is relatively short.

6. DEALING WITH COMPLICATIONS IN ECONOMIC EVALUATIONS

In this section several departures from previous simplifying conditions are examined. Results of revenue requirement analysis (perspective B) and present-worth analysis (perspective A) are again shown to be identical, except in special situations where timing of cash flows for income taxes is affected by assumptions inherent to each method.

6.1 Effects of Accelerated Depreciation and Minimum Asset Depreciation Range Life

Because of recent changes in income tax law, most studies based on the RR method tend to incorporate sophisticated provisions that go considerably beyond a key assumption underlying example 2 — that book depreciation equals tax depreciation. Changes in tax regulations have occurred in recent years that allow accelerated depreciation to be used in computing income taxes, in addition to a tax life that is less than the average useful life of an asset. These are two of the major changes that result in depreciation charges for tax purposes being much greater in the early years of an asset's life than straight-line depreciation charges allowed for rate-setting purposes. Equations (11) and (13) can be modified to account for these regulations as well as for other factors, but the algebraic manipulations involved tend to divert attention from the basic purpose of the analysis (i.e., analysis of differences between alternatives) because they become quite tedious. The reader interested in these modified equations is referred to the book by Jeynes.[2]

To deal with the two "complications" that are the subject of this section, a tabular analysis procedure is again recommended. Thus, algebraic manipulations involving Eqs. (9–13) are not necessary per se. By using a tabular format, it is demonstrated that the RR method and PW analysis produce identical results. Example 2 is initially utilized for this purpose.

In computing a utility's income taxes, accelerated depreciation methods such as sum-of-the-years digits (SYD) or double declining balance (DDB) may be used. Furthermore, a tax life less than an asset's average life can usually be employed in accordance with the Revenue Act of 1971.

The Asset Depreciation Range (ADR) system established by this act makes it permissible to use a minimum tax life that is roughly 80% of the average life for most assets. The effect of these two provisions (accelerated depreciation and minimum ADR tax life) alters substantially the revenue requirement and present worth of a particular investment opportunity.

Referring now to example 2, suppose the revenue requirement is desired when SYD depreciation is used with an ADR minimum tax life of three years. All other aspects of the problem are unchanged. From Eq. (13) it is apparent that income taxes will now reflect year-by-year differences in book depreciation (D_B) and tax depreciation (D_t). Determination of an annual revenue requirement for this modified version of example 2 is shown in Table 15, where only changes from Table 5 are given.

Note that debt return and equity return in both Tables 5 and 15 are based on book depreciation. Therefore, only columns 6 and 7 of Table 5 are affected when $D_B \neq D_t$. Also, the revenue requirement totals \$254,400 in both tables, but the *timing* of the requirement in Table 15 differs because of deferred taxes resulting from accelerated amortization of the

Table 15. Annual revenue requirement for example 2 when $D_t \neq D_B$

Year	Income taxes, T^a	Revenue requirement columns 2 + 3 + 4 + 5 (from Table 5) + T
1	9240 + 21,000 − 42,000 = −11,760	50,160
2	6930 + 21,000 − 28,000 = −70	59,120
3	4620 + 21,000 − 14,000 = 11,620	68,080
4	2310 + 21,000 − 0 = 23,310	77,040

[a] $T = \frac{t}{1-t}(f_E R_E + D_B - D_t)$. D_B is \$21,000/year as in Table 5, and D_t is calculated as follows:

$$SYD = \frac{3(4)}{2} = 6; \quad D_1 = 3/6\ (\$84{,}000) = \$42{,}000$$

$$D_2 = 2/6\ (\$84{,}000) = \$28{,}000$$

$$D_3 = 1/6\ (\$84{,}000) = \$14{,}000$$

investment. The result is a lower levelized RR when accelerated depreciation and a minimum ADR tax life are applicable. Specifically, the levelized RR of Table 15 at $i' = 12\%$ is

$$\overline{RR} = \$50{,}160 + \$8960 \overset{1.359}{(A/G,\ 12\%\ 4)}$$
$$= \$62{,}337\ .$$

This is 3.1% less than the $\overline{RR}$ calculated from Table 5.

To check the estimate of levelized RR that results from an after-tax present-worth analysis against the \$62,337 determined above, the "Depreciation" column of Table 8 must be modified. This change affects other entries of Table 8 as shown in Table 16. The present worth of the ATCF column at $R_E = 14.67\%$ is \$89,211, and the uniform annual equivalent cost is $-\$89{,}211 \overset{0.348}{(A/P,\ 14.67\%,\ 4)} = -\$31{,}045$. From Eq. 14 the levelized RR is \$31,045/0.5 = \$62,090, which agrees well with the RR method determination of \$62,337. The error of 0.4% results primarily from round-off in calculation of the discounting factors.

Table 16. After-tax cash flow analysis for example 2 with accelerated depreciation and a tax life of three years

Year	Net before-tax cash flow	Depreciation[a]	Taxable income	Income taxes	After-tax cash flow[b]
0	−\$63,000				−\$63,000
1	−31,680	−\$42,000	−\$73,680	+\$36,840	−90
2	−31,260	−28,000	−59,260	+29,630	−6,880
3	−30,840	−14,000	−44,840	+22,420	−13,670
4	−30,420	-0-	−30,420	+15,210	−20,460

[a]SYD depreciation for tax purposes is calculated in Table 15.

[b]ATCF = net BTCF + principal of loan cash flow + income taxes.

6.2 Example 3 — Treatment of Inflation

In this discussion the complication of dealing with inflation is utilized to illustrate further the equivalence of the RR and the PW method of economic evaluation. Example 3, which is fashioned after an industrial power plant problem investigated in ref. 7, is used for this purpose. It is a more difficult problem than example 2 and reflects many realistic aspects of industrial problems.

Suppose the investment for a certain capital asset is $123.6 million, payable entirely in 1985 at the start of commercial operation. The estimated useful life is five years, but a tax life of four years can be used by the company. Sum-of-the-years digits depreciation is utilized over the four-year life of the asset, with no salvage value considered. To simplify this problem further, it is assumed that no investment tax credit can be taken. Other pertinent data to the economic evaluation are listed below:

1. annual fuel costs in 1985 (estimated at start of project), $\$23.0 \times 10^6$;
2. annual O&M costs in 1985 (estimated at start of project), $\$3.5 \times 10^6$;
3. bonds as a fraction of total investment, 0.25;
4. return on bonds (includes adjustment for inflation), 0.083;
5. equity as a fraction of total investment, 0.75;
6. return to equity (includes adjustment for inflation), 0.153;
7. property insurance rate (decimal), 0.0025;
8. property tax rate (decimal), 0.0060;
9. state income tax rate (decimal), 0.04;
10. federal income tax rate (decimal), 0.48;
11. average annual rate of inflation (decimal), 0.06;
12. project start-up date (commercial operation), 1985.

The purpose of the analysis is to compare the revenue requirement with the present-worth technique at the start of commercial operation and by doing so demonstrate that both procedures provide identical results. In addition, it is desired to investigate the effect that inflation has on the economic attractiveness of example 3. The first procedure applied to example 3 is the revenue requirement methodology.

To determine the year-by-year revenue requirement and the levelized revenue requirement for this problem, the following definition of RR is again utilized:

$$RR = \text{carrying charges related to the capital investment (CC)} + \text{annual operating costs (OC)} \ . \qquad (16)$$

Carrying charges and taxes, respectively, consist of these components (expressed in dollars):

$$CC = D_B + f_E R_E + f_D R_D + T \ , \qquad (17)$$

$$T = \frac{t_e}{1 - t_e} \cdot (f_E R_E + D_B - D_T) \ , \qquad (18)$$

where all terms are defined in Sect. 3.

Furthermore, the effective income tax rate (t_e) is defined as follows:

$$t_e = (1 - s)f + s \ , \qquad (19)$$

where

s = state income tax rate (decimal),

f = federal income tax rate (decimal).

The remaining portion of RR consists of annual out-of-pocket costs:

$$OC = F + OM + PTI \ , \qquad (20)$$

where

F = fuel costs

OM = operation and maintenance costs,

PTI = property taxes and insurance.

An inflation rate of 6% per year during the life of the project is assumed for all cash flows that respond to inflationary pressures. In this problem, responsive cash flows are fuel costs, operation and maintenance costs, and property insurance. Estimates of these quantities were initially made in 1976 dollars and inflated at 6% per year to arrive at the 1985 estimates given previously. All other components of RR are assumed fixed and are not responsive to inflation. By utilizing Eq. (16), the year-by-year revenue requirement in view of a 6% inflation rate is determined in Table 17. Tax depreciation, calculated with the SYD method, is as follows:

$$D_1 = 4/10\ (123.60) = 49.44,$$
$$D_2 = 3/10\ (123.60) = 37.08,$$
$$D_3 = 2/10\ (123.60) = 24.72,$$
$$D_4 = 1/10\ (123.60) = 12.36.$$

In this example, the tax-adjusted weighted cost of capital to the utility is computed with Eq. (10):

$$i' = (1 - t_e)f_D R_D + f_E R_E = 0.1252\ .$$

The present worth of RR (PWRR) is computed at a discount rate of $i' =$ 12.52% in the following manner:

$$\begin{aligned} \text{PWRR}(12.52\%) &= 60.1(P/F,\ 12.52\%,\ 1) + 67.9(P/F,\ 12.52\%,\ 2) \\ &\quad + 75.8(P/F,\ 12.52\%,\ 3) + 84.1(P/F,\ 12.52\%,\ 4) \\ &\quad + 92.0(P/F,\ 12.52\%,\ 5) = \underline{\$263.7 \times 10^6}\ . \end{aligned}$$

Another method of comparing alternatives that was used extensively in Sect. 3 involves the use of a "levelized" revenue requirement. The levelized RR ($\overline{RR}$) is an equal annual revenue requirement expressed over the project's useful life in view of the time value of money. This situation is illustrated in Fig. 9. The $\overline{RR}$ in Fig. 9 is computed as follows at $i' = 12.52\%$:

$$RR = \text{PWRR}(12.52\%)\cdot(A/P,\ 12.52\%,\ 5)\ ,$$

where

$$(A/P,\ 12.52\%,\ 5) = \frac{0.1252(1.1252)^5}{(1.1252)^5 - 1} = 0.281\ ;$$

thus,

$$RR = (\$263.7 \times 10^6)(0.281) = \$74.1 \times 10^6\ .$$

Table 17. Annual revenue requirement in response to inflation ($\$10^6$) — example 3

(1) Year[a]	(2) Unrecovered investment[b]	(3) Book deprec. (D_B)	(4) Tax deprec. (D_T)	(5) Fuel + O&M inflated at 6%	(6) Property tax	(7) Property ins. inflated at 6%	(8) R_D = debt return[c] 8.3% of (2)(0.25)	(9) R_E = equity return[c] 15.3% of (2)(0.75)	(10) T = income taxes[d]	(11) Revenue requirement (rounded) [(3) + (8) + (9) + (10)] + [(5) + (6) + (7)]
1	123.60	24.72	49.44	28.1	0.7	0.3	2.6	14.2	−10.52[e]	31.0 + 29.1 = 60.1
2	98.88	24.72	37.08	29.8	0.7	0.3	2.1	11.3	−1.06	37.1 + 30.8 = 67.9
3	74.16	24.72	24.72	31.5	0.7	0.4	1.5	8.5	8.50	43.2 + 32.6 = 75.8
4	49.44	24.72	12.36	33.5	0.7	0.4	1.0	5.7	18.06	49.5 + 34.6 = 84.1
5	24.72	24.72	0	35.4	0.7	0.4	0.5	2.8	27.52	55.5 + 36.5 = 92.0

[a] Estimated useful life is five years; tax life is four years.

[b] Based on beginning-of-year book value, where book value is computed with the straight-line depreciation method and no salvage value.

[c] Capitalization for this project is 25% borrowed funds and 75% equity funds.

[d] The effective income tax rate, t_e, is $(1 - 0.04)(0.48) + 0.04 = 0.50$.

[e] Income tax (T) = $\left(\frac{0.5}{1 - 0.5}\right)(R_E + D_B - D_T)$, see Eq. (13).

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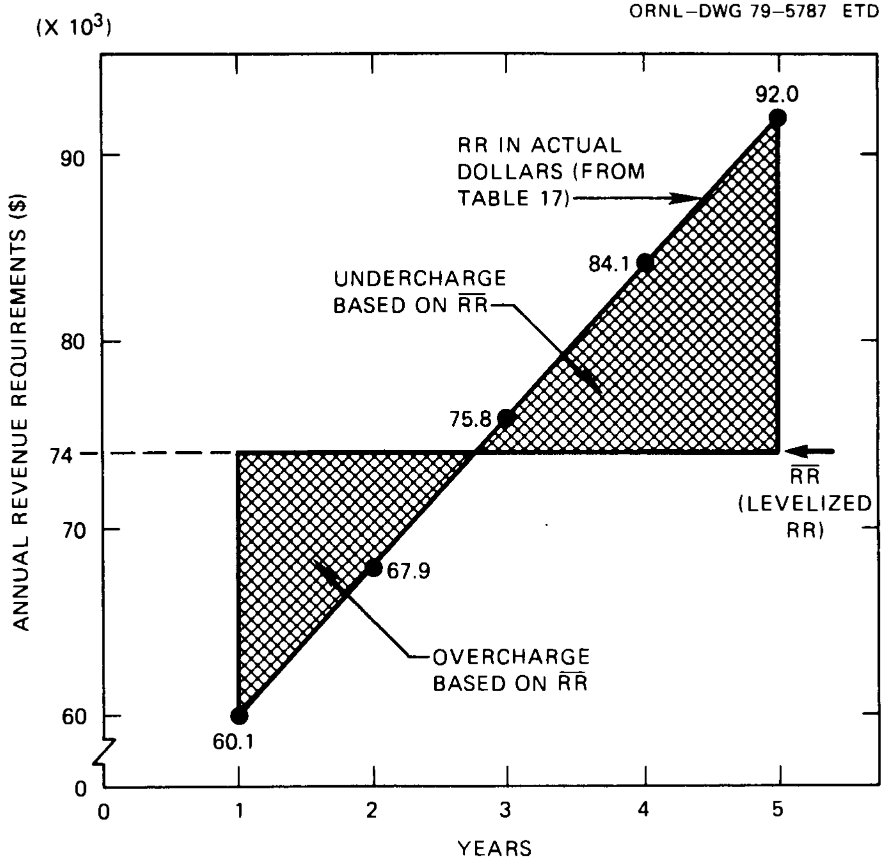

Fig. 9. Graphical summary of revenue requirements in view of 6% inflation rate.

To check these hand calculations, the LEVEL$ subroutine of the modified ORCOST-II code for estimating the cost of power from steam-electric power plants was utilized.[8] The first computer run for example 3 was based on an average inflation rate of 6% per year, with return on bonds = 8.3% and return on common stock (equity) = 15.3%. Results are shown in Table 18, where it can be observed that the annual "gross revenues" are approximately equal to the revenue requirements in column 11 of Table 17. The small differences that exist are primarily due to computer rounding to the nearest tenth of a million dollars. Column 10 of Table 17 represents the sum of state and federal income taxes itemized in Table 18. The levelized revenue requirement from the LEVEL$ subroutine is $\$74.20 \times 10^6$, and the present worth is $\$264.2 \times 10^6$, both determined at $i' = 12.52\%$. These results closely match the values calculated from Table 17, $\$74.1 \times 10^6$ and $\$263.7 \times 10^6$ respectively.

Table 18. Example 3 with inflation at 6% per year (75% equity, book life = 5 years, tax life = 4 years)

Annual cash flows, $million

Year of operation	Gross revenue	Fuel expense	O&M expense	Misc. expense	Property insurance	Bond interest	Preferred stock	Common stock	Property tax	State income tax	Federal income tax	Book depreciation
1.0	60.1	24.4	3.7	0.0	0.3	2.6	0.0	14.2	0.7	−0.8	−9.7	24.7
2.0	68.0	25.9	3.9	0.0	0.3	2.1	0.0	11.3	0.7	−0.1	−0.9	24.7
3.0	76.0	27.5	4.1	0.0	0.4	1.5	0.0	8.5	0.7	0.7	7.9	24.7
4.0	84.1	29.1	4.4	0.0	0.4	1.0	0.0	5.7	0.7	1.4	16.6	24.7
5.0	92.4	30.8	4.7	0.0	0.4	0.5	0.0	2.8	0.7	2.2	25.4	24.7

$\overline{RR} = \$74.2 \times 10^6$

$PWRR(12.51\%) = \$264.2 \times 10^6$

Another computer run is included as Table 19, assuming no inflation. In this case all economic factors were considered at their 1976 levels. This was done to analyze the effect of inflation between Tables 18 and 19. The inflation-free cost of debt and equity capital in Table 19 is calculated as follows:

$$1 + \text{cost of capital (no inflation)} = \frac{1 + \text{cost of capital (with inflation)}}{1 + \text{average rate of inflation}} .$$

Thus, *in the absence of inflation*, the cost of capital is

$$\text{Debt} \qquad R_D = \frac{1.083}{1.060} - 1 = 0.0217 ,$$

$$\text{Equity} \qquad R_E = \frac{1.153}{1.060} - 1 = 0.0877 .$$

The tax-adjusted average cost of money, for discounting purposes, is 0.0685. When the gross revenues (i.e., annual revenue requirements) in Table 19 are discounted, the present worth of the revenue requirement is $\$149.1 \times 10^6$, and the $\overline{RR}$ is $\$36.2 \times 10^6$. Thus it can be seen that in view of inflation at 6% per year from 1976 to 1990, the revenues required to make the project viable have more than doubled.

Now this same problem is worked with the PW method when inflation averages 6% per year. In the following analysis, assumptions are identical to those employed in the previous revenue requirement analysis. To carry out the calculations, the format suggested by Table 2 is used. In this regard, data essential to an after-tax analysis of the project's present worth are provided in Table 20.

The present worth of the ATCF column in Table 20 at $R_E = 15.3\%$ is $-\$122.67 \times 10^6$. The equivalent uniform annual cost equals $(-\$122.67 \times 10^6)\ \overset{0.3004}{(A/P, 15.3\%, 5)} = -\$36.85 \times 10^6$. Finally, from Eq. (14) the levelized revenue requirement is $\$36.85/0.5 = \$73.71 \times 10^6$. As expected, this is quite close to the $\overline{RR}$ calculated in Table 18. The small difference in results (about 0.5%) is due to rounding errors arising from calculation of discounting factors and could be reduced by carrying greater accuracy through the analysis.

Table 19. Example 3 with inflation at 0% per year (75% equity, book life = 5 years, tax life = 4 years)

Annual cash flows, $million

Year of operation	Gross revenue	Fuel expense	O&M expense	Misc. expense	Property insurance	Bond interest	Preferred stock	Common stock	Property tax	State income tax	Federal income tax	Book depreciation
1.0	26.3	13.6	2.1	0.0	0.2	0.4	0.0	4.8	0.4	−0.8	−9.0	14.6
2.0	31.6	13.6	2.1	0.0	0.2	0.3	0.0	3.8	0.4	−0.3	−3.2	14.6
3.0	36.9	13.6	2.1	0.0	0.2	0.2	0.0	2.9	0.4	0.2	2.7	14.6
4.0	42.2	13.6	2.1	0.0	0.2	0.2	0.0	1.9	0.4	0.7	8.5	14.6
5.0	47.6	13.6	2.1	0.0	0.2	0.1	0.0	1.0	0.4	1.2	14.4	14.6

$\overline{RR}$ = \$36.2 × 10^6

PWRR(6.85%) = \$149.1 × 10^6

Table 20. Annual after-tax cash flow taking account of inflation ($\$10^6$) — example 3

(1) End of year	(2) Unrecovered investment[a]	(3) Depreciation		(4) Loan cash flow[b]		(5) Fuel + O&M inflated at 6%	(6) Property taxes and insurance	(7) Net before-tax cash flow[c]	(8) Taxable income[d]	(9) Income taxes[e]	(10) After-tax cash flow[f]
		Book	Tax	Principal	Interest at 8.3%						
0								−123.6 + 31.0 = −92.6[g]			−92.6
1	123.60	−24.72	−49.44	−6.2	−2.6	−28.1	−1.0	−31.7	−81.14	+40.57	+2.67
2	98.88	−24.72	−37.08	−6.2	−2.1	−29.8	−1.0	−32.9	−69.98	+34.99	−4.11
3	74.16	−24.72	−24.72	−6.2	−1.5	−31.5	−1.1	−34.1	−58.82	+29.41	−10.89
4	49.44	−24.72	−12.36	−6.2	−1.0	−33.5	−1.1	−35.6	−47.96	+23.98	−17.82
5[h]	24.72	−24.72	0	−6.2	−0.5	−35.4	−1.1	−37.0	−37.00	+18.50	−24.70

[a]Based on beginning-of-year book value, where book value is computed with the straight-line depreciation method and no salvage value.

[b]Twenty-five percent of investment capital is borrowed (i.e., $\$31 \times 10^6$) and is repaid in equal annual amounts of $\$6.2 \times 10^6$. Interest is 0.083(0.25) (col. 2) per year.

[c]Column 5 + column 6 + interest on debt capital.

[d]Column 7 + tax depreciation.

[e]Column 8 × 0.5.

[f]Column 7 + principal of loan (col. 4) + col. 9.

[g]Equity funds disbursed at start of project = 0.75 ($-\$123.6 \times 10^6$) = $-\$92.6 \times 10^6$.

[h]Estimated useful life is five years; tax life is four years.

6.3 Consideration of Investment Tax Credits

Investment in new plant facilities generally benefits the nation's economy. The federal government can control to a high degree such investments by reducing a firm's income tax liability whenever investment in a new plant occurs. These tax reductions are termed investment tax credits (ITC), and they are based on a fixed percentage of eligible costs of new (or used) plant capacity. Different ITC percentages apply, depending on the purpose of the investment, its expected life, and whether the assets acquired are new or used.

Before incorporating investment tax credits into example 3, two characteristics of these credits must be noted:

1. Book depreciation (D_B), which is usually based on the straight-line method, is unaffected by the ITC and continues to be calculated over the useful life of the investment. Similarly, tax depreciation is not affected by the ITC and is normally computed with an accelerated method over an acceptable ADR tax life.

2. The repayment of debt capital is assumed to remain uniform during each year of useful life. That is, of the $\$24.72 \times 10^6$ straight-line depreciation each year in example 3, 25% of it ($\$6.2 \times 10^6$) is used to retire debt so that no debt remains after the fifth year. This is an important assumption inherent to both evaluation procedures being considered.

In view of these features of investment tax credits, it is possible to modify Table 17 so that an $\overline{RR}$ can be determined in view of a 10% tax credit on the $\$123.6 \times 10^6$ investment. (For purposes of illustration it is assumed a 10% ITC applies to example 3.)

The accepted way of taking investment tax credits into account with the RR method is to reduce the year 1 amount by $ITC/(1 - t_e)$. This reduction is included as a tax credit under the "income taxes" column, and no other adjustments are made in the yearly revenue requirements of Table 17. Such an approach has the implicit assumption that the total investment will be financed with bonds and equity rather than with just the *reduced* capital investment, which in this case is 90% of $\$123.6 \times 10^6$.

For the example problem under consideration, income taxes in column 10 of Table 17 are modified in year 1 to reflect 10% of the ITC:

Year	Income taxes
1	$-10.52 - (12.36/0.5) = -35.24$
2	−1.06
3	8.50
4	18.06
5	27.52

Now the $\overline{RR}$ is $\$67.9 \times 10^6$ after recalculating column 11 of Table 17. This compares with an $\overline{RR}$ of $\$74.1 \times 10^6$ when the investment tax credit is not considered, or a decrease of $\$6.2 \times 10^6$ (8.4%).

To compare the above results with those obtained by the PW method, it is necessary only to change two entries in Table 20 prior to recalculating the present worth of after-tax cash flow in view of the 10% ITC. Both new entries are made on the "year 0" line of Table 20 as follows:

End of year	Col. 9 income taxes	Col. 10 after-tax cash flow
0	+12.4	−80.2

From the above it can be seen that the 10% ITC is taken shortly after funds are disbursed for the purchase of the capital asset, and thus it immediately reduces income taxes payable by the firm (column 9). The ITC appears in year 0 rather than in year 1 because with quarterly federal income tax payments the credit would be taken closer to "the present" (year 0) than to the end of year 1. This is a subtle difference between the RR and PW methods of economic evaluation that invalidates their equivalence when ITCs are considered. No other entries of Table 20 are affected because book depreciation and the resultant loan cash flow (column 4) are not altered by an investment tax credit.

The present worth of ATCF in Table 20, adjusted for the 10% ITC, is computed at $R_E = 15.3\%$ and equals $-\$110.28 \times 10^6$. The equivalent uniform annual cost at 15.3% equals $-\$33.15 \times 10^6$. From Eq. (14) the levelized revenue requirement is $33.15/0.5 = \$66.3 \times 10^6$. This is $\$1.6 \times 10^6$ (2.4%) less than the levelized RR that includes the same ITC taken at the *end* of year 1. The reason for the difference lies in the *timing* of the tax credit — in the RR method the ITC is assumed to be taken at the end of year 1, and with the present-worth procedure the credit is taken immediately.

6.4 Consideration of Salvage Values

When plant items are removed from service, a net salvage value is usually incurred which is the difference between cash receipts and removal costs associated with the transaction. A net salvage value may be positive or it may be negative. If the anticipated net salvage value is 10% or less of the investment, the Internal Revenue Service generally permits a firm to use a zero salvage value in computing the annual book and tax depreciation for the item.[9] In this situation, carrying charges in the RR method are unaffected, but the actual cost of owning the asset over its useful life is affected because a cash flow equal to 10% of the item's first cost is anticipated at the end of useful life. This gain is taxed at the ordinary rate of t_e. One way to approximate this change in actual $\overline{RR}$ brought about by a positive net salvage value (originally estimated to be less than 10% of the investment cost) is to reduce the levelized RR by

$$t_e \cdot S(A/F, i'\%, N) ,$$

where

S = estimated salvage value (less removal costs),
N = number of years of useful service from the asset,
i' = after-tax weighted average cost of money,
$(A/F, i'\%, N)$ = annual uniform sinking-fund factor.

However, if the net salvage value is expected to be greater than 10% of the investment, tax and book depreciation amounts each year must be recomputed. In this situation, tax depreciation is reduced by whatever amount the salvage value exceeds 10% of the original cost. This in turn will affect carrying charges and hence the revenue requirement. Because ADR procedures for dealing with salvage values greater than 10% of original cost are rather complicated, the topic is not discussed further here. The interested reader is referred to ref. 10.

6.5 Summary of Dealing with Complications

Two different problems have been utilized in Sect. 6 to demonstrate how several different conditions affect the two evaluation procedures being considered. Example 2 first appeared in Sect. 3, and in this section it was observed that use of accelerated depreciation and a minimum ADR class life resulted in a 3.1% reduction in $\overline{RR}$ relative to an earlier solution in which $D_B = D_T$. Example 3 was introduced in this section to demonstrate further several realistic complicating factors in after-tax economic studies of industrial power plants. Inflation in economic evaluations was considered in example 3, and it was demonstrated that when investment tax credits and salvage values were ignored, both methods of economic assessment provided identical results. Investment tax credits were next included in the determination of $\overline{RR}$, and it was shown that a 10% ITC reduced the $\overline{RR}$ by 8.4%. A salvage value equal to less than 10% of the cost of the original investment was briefly discussed. In summary, most "refinements" considered in Sect. 6 resulted in small changes in $\overline{RR}$ and PW relative to those calculated in the simplified case where $D_B = D_T$.

7. CONCLUSIONS AND RECOMMENDATIONS

From the foregoing discussion and analysis of three example problems, it is concluded that the revenue requirement and present-worth methods of economic evaluation are equivalent for any combination of debt and equity financing (Table 11) and for different perspectives that could be used to evaluate the problems. This is true when an after-tax weighted cost of money (i') is used for discounting purposes in the RR method and when the return to equity (R_E) is employed to determine a project's present worth.

An effective income tax rate of 0.50 was utilized throughout this report to demonstrate that both methods produce identical results. However, it is true in general that both methods are equivalent for any reasonable value of the effective income tax and for any financing scheme. Most industrial problems are evaluated with a value of t_e near 0.50 — this motivated the use of a 50% tax rate.

A conclusion from example 1 was that the present-worth criterion is generally preferred to the internal rate of return method of discounted cash flow analysis. Additionally, the IRR criterion requires many trial-and-error attempts for solution and is therefore computationally cumbersome. The PW method does require that an appropriate discount rate be specified, however.

Example 2 was used extensively to demonstrate equivalence of the RR and PW methods through several approaches. For either straight-line or accelerated depreciation with a minimum ADR tax life, both methods were shown to be equivalent. It is interesting to note that in all comparisons based on example 2, the levelized revenue requirement was 0.2% less than the estimate of $\overline{RR}$ derived from an after-tax present-worth analysis of costs only. [Equation (14) was the source of the estimated $\overline{RR}$.] This small "error" can be explained largely by the rounding of interest factors in the analysis.

Example 2 was also used to illustrate differences in perspective (i.e., utility management and the outside investor) as reflected by two different discount rates that are most commonly utilized in revenue requirement studies. These rates are the tax-adjusted average cost of capital (i') and the non tax-adjusted average cost of capital (i^*). Based on the findings in this report, the tax-adjusted average cost of capital is recommended for purposes of establishing the equivalence and consistency of the PW and RR methods of economic evaluation. The "error" introduced by discounting annual revenue requirements with the non tax-adjusted average cost of capital is 2% for examples 2 and 3. Appendix B is included to substantiate further the "correctness" of discounting annual revenue requirements at the tax-adjusted rate. Other discount rates can be employed to show equivalence of numerous analytical perspectives as presented in Table 12.

Because of regulatory restrictions faced by firms that typically utilize the RR methodology, it was concluded that certain economic conditions can exist such that the RR and the PW methods, as used by competitive industry, provide different indications of project profitability. However, these conditions invalidate the common assumptions underlying the application of both methods, and the conclusion that the methods are equivalent is valid when only identical assumptions underlie their use.

Concerning the analysis of multiple alternatives, two mutually exclusive projects were investigated with each method. It was concluded that preference orderings based on economics were identical for the revenue requirement procedure as well as the present-worth method. In addition, it was shown that the ratio of present worth for one alternative relative to the other was identical to the ratio of levelized revenue requirements for both alternatives. The conclusion is that in addition to being equivalent methods of economic comparison, results obtained with the RR and PW procedures are also *consistent* as evidenced by identical criterion ratios for the two projects considered (see Table 14).

Several complications arising from current income tax laws were evaluated in example 3, which represented a more realistic situation than was afforded by either example 1 or 2. Example 3 was solved by both methods of economic evaluation in consideration of inflation. Again, equivalence was demonstrated, and hand calculations were confirmed by analyzing the problem with the LEVEL$ subroutine of the modified ORCOST-II computer code. The effect of investment tax credits was next quantified with the RR and PW methods. The conclusion was reached that each method uses a different assumption regarding the timing of the credit, and thus the equivalence of the procedures could not be established. Finally, the treatment of salvage values was discussed. Because of different assumptions inherent to each method regarding timing of income taxes associated with salvageable items, the equivalence of the RR and PW methods would be negated.

If tax provisions such as those considered in Sect. 6 are present in a problem, the assumptions inherent to the PW and RR evaluation procedures are not identical, and different results are obtained. In the absence of special tax provisions that tend to differ from one industry to another, it was shown that the RR and PW methods are equivalent and consistent for purposes of evaluating the relative economics of industrial power plants.

Consequently, the two methods can be used in feasibility studies of alternative industrial power plant projects. It is recommended, however, that the method best understood by the ultimate decision maker be used so that communication and acceptance of study results are not impeded. The perspective of the analysis in some cases will dictate whether the "customer viewpoint" should be utilized or whether the perspective of owners of the firm should be taken. It is demonstrated herein that if assumptions applicable to the analysis are the same for the RR and PW methods, both perspectives result in attainment of the same objective. In summary, the eventual choice of an economic evaluation procedure depends largely on "what language" the decision maker comprehends.

REFERENCES

1. E. L. Grant, W. G. Ireson, and R. S. Leavenworth, *Principles of Engineering Economy*, 6th ed., Ronald Press, New York, 1976.
2. P. H. Jeynes, *Profitability and Economic Choice*, Iowa State University Press, Ames, 1968.
3. J. B. Oso, "The Proper Role of the Tax-Adjusted Cost of Capital in Present Value Studies," *The Engineering Economist*, vol. 24, No. 1 (Fall 1978), pp. 1–12.
4. Electric Power Research Institute, *Technical Assessment Guide*, EPRI PS-866-SR, June 1978, p. V-1 ff.
5. Commonwealth Edison Company, *Engineering Economics*, Chicago, 1975.
6. E. P. DeGarmo, J. R. Canada, and W. G. Sullivan, *Engineering Economy* (6th ed.), Macmillan, New York, 1979.
7. O. H. Klepper, L. C. Fuller, and M. L. Myers, *Assessment of a Small Pressurized Water Reactor for Industrial Energy*, ORNL/TM-5881 (October 1977).
8. Personal communication with L. C. Fuller, June 1978.
9. L. E. Bussey, *The Economic Analysis of Industrial Projects*, Prentice-Hall, Englewood Cliffs, N.J., 1978.
10. Construction Plant Department, American Telephone and Telegraph Company, *Engineering Economy — A Manager's Guide to Economic Decision Making*, 3d ed., McGraw-Hill, New York, 1977.

APPENDICES

Appendix A

TERMS USED IN ENGINEERING ECONOMY*

AMORTIZATION—a. 1) as applied to a capitalized asset, the distribution of the initial cost by periodic charges to operations as in depreciation. Most properly applies to assets with indefinite life; 2) the reduction of a debt by either periodic or irregular payments; b. a plan to pay off a financial obligation according to some prearranged program.

ANNUAL EQUIVALENT—a. in *Time Value of Money (q.v.)*, a uniform annual amount for a prescribed number of years that is equivalent in value to the present worth of any sequence of financial events for a given interest rate; b. one of a sequence of equal end-of-year payments which would have the same financial effect when interest is considered as another payment or sequence of payments which are not necessarily equal in amount or equally spaced in time.

ANNUITY—a. an amount of money payable to a beneficiary at regular intervals for a prescribed period of time out of a fund reserved for that purpose; b. a series of equal payments occurring at equal periods of time.

BOOK VALUE—a. the recorded current value of an asset. First cost less accumulated depreciation, amortization, or depletion; b. original cost of an asset less the accumulated depreciation; c. the worth of a property as shown on the accounting records of a company. It is ordinarily taken to mean the original cost of the property less the amounts that have been charged as depreciation expense.

CAPITAL—a. the financial resources involved in establishing and sustaining an enterprise or project. (see *Investment and Working Capital*); b. a term describing wealth which may be utilized to economic advantage. The form that this wealth takes may be as cash, land, equipment, patents, raw materials, finished products, etc.

CAPITAL RECOVERY—a. charging periodically to operations amounts that will ultimately equal the amount of capital expenditure (see *Amortization, Depletion, and Depreciation*); b. the replacement of the original cost of an asset plus interest; c. the process of regaining the net investment in a project by means of revenue in excess of the costs from the project. (Usually implies amortization of principal plus interest on the diminishing unrecovered balance).

CAPITAL RECOVERY FACTOR—a factor used to calculate the sum of money required at the end of each of a series of periods to regain the net investment of a project plus the compounded interest on the unrecovered balance.

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*Source: American National Standards Institute, "Glossary of Technical Terms Used in Engineering Economy," ANSI Z94.5, 1972.

CASH FLOW—a. the flowback of profit plus depreciation from a given project; b. the real dollars passing into and out of the treasury of a financial venture.

COMMON COSTS—costs which cannot be identified with a given output of products, operations, or services.

COMPOUND AMOUNT FACTOR—a. the function of interest rate and time that determines the compound amount from a stated initial sum; b. a factor which when multiplied by the single sum or uniform series of payments will give the future worth at compound interest of such single sum or series.

COMPOUND INTEREST—a. the type of interest that is periodically added to the amount of investment (or loan) so that subsequent interest is based on the cumulative amount; b. the interest charges under the condition that interest is charged on any previous interest earned in any time period, as well as on the principal.

COMPOUNDING PERIOD—the time interval between dates at which interest is paid and added to the amount of an investment or loan. Designates frequency of compounding.

DECLINING BALANCE DEPRECIATION—also known as *percent on diminishing value*. A method of computing depreciation in which the annual charge is a fixed percentage of the depreciated book value at the beginning of the year to which the depreciation applies.

DEPRECIATED BOOK VALUE—the first cost of the capitalized asset minus the accumulation of annual depreciation cost charges.

DEPRECIATION—a. 1) decline in value of a capitalized asset; 2) a form of capital recovery applicable to a property with two or more years' life span, in which an appropriate portion of the asset's value is periodically charged to current operations; b. the loss of value because of obsolescence or due to attrition. In accounting, depreciation is the allocation of this loss of value according to some plan.

DISCOUNTED CASH FLOW—a. the present worth of a sequence in time of sums of money when the sequence is considered as a flow of cash into and/or out of an economic unit; b. an investment analysis which compares the present worth of projected receipts and disbursements occurring at designated future times in order to estimate the rate of return from the investment or project.

ENGINEERING ECONOMY—1) the application of engineering or mathematical analysis and synthesis to economic decisions; 2) a body of knowledge and techniques concerned with the evaluation of the worth of commodities and services relative to their cost; 3) the economic analysis of engineering alternatives.

FIRST COST—the initial cost of a capitalized property, including transportation, installation, preparation for service, and other related initial expenditures.

FUTURE WORTH—a. the equivalent value at a designated future date based on *time value of money*; b. the monetary sum, at a given future time, which is equivalent to one or more sums at given earlier times when interest is compounded at a given rate.

INCREMENT COST—the additional cost that will be incurred as the result of increasing the output one more unit. Conversely, it can be defined as the cost that will not be incurred if the output is reduced one unit. More technically, it is the variation in output resulting from a unit change in input. It is known as the marginal cost.

INTEREST—a. 1) financial share in a project or enterprise; 2) periodic compensation for the lending of money; 3) in economy study, synonymous with *required return*, expected profit, or *charge* for the use of capital; b. the cost for the use of capital. Sometimes referred to as the *Time Value of Money (q.v.)*.

INTEREST RATE—the ratio of the interest payment to the principal for a given unit of time and is usually expressed as a percentage of the principal.

INTEREST RATE, EFFECTIVE—an interest rate for a stated period (per year unless otherwise specified) that is the equivalent of a smaller rate of interest that is more frequently compounded.

INTEREST RATE, NOMINAL—the customary type of interest rate designation on an annual basis without consideration of compounding periods. The usual basis for computing periodic interest payments.

INVESTMENT—1) as applied to an enterprise as a whole, the cost (or present value) of all the properties and funds necessary to establish and maintain the enterprise as a going concern. The *capital* tied up in the enterprise or project; 2) any expenditure which has substantial and enduring value (at least two years' anticipated life) and which is therefore capitalized.

INVESTOR'S METHOD—(see *Discounted Cash Flow Method*).

LIFE—1) economic: that period of time after which a machine or facility should be discarded or replaced because of its excessive costs or reduced profitability. The economic impairment may be absolute or relative; 2) physical: that period of time after which a machine or facility can no longer be repaired in order to perform its design function properly; 3) service: the period of time that a machine or facility will satisfactorily perform its function without major overhaul.

MARGINAL ANALYSIS—an economic concept concerned with those elements of costs and revenue which are associated directly with a specific course of action, normally using available current costs and revenue as a base and usually independent of traditional accounting allocation procedures.

MULTIPLE STRAIGHT-LINE DEPRECIATION METHOD—a method of depreciation accounting in which two or more straight line rates are used. This method permits a predetermined portion of the asset to be written off in a fixed number of years. One common practice is to employ a straight line rate which will write off 3/4 of the cost in the first half of the anticipated service life; with a second straight line rate to write off the remaining 1/4 in the remaining half life.

PRESENT WORTH—a. the equivalent value at the present, based on *time value of money*; b. 1) the monetary sum which is equivalent to a future sum(s) when interest is compounded at a given rate; 2) the discounted value of future sums.

PRESENT WORTH FACTOR—a. a mathematical expression also known as the present value of an annuity of one; b. one of a set of mathematical formulas used to facilitate calculation of present worth in economic analyses involving compound interest.

PROFITABILITY INDEX—the rate of return in an economy study or investment decision when calculated by the *Discounted Cashflow Method* or the *Investor's Method (q.v.)*.

RATE OF RETURN—1) the interest rate at which the present worth of the cash flows on a project is zero; 2) the interest rate earned by an investment.

REQUIRED RETURN—the *minimum* return or profit necessary to justify an investment. Often termed *interest, expected* return or profit, or *charge for the use of capital*. It is the minimum acceptable percentage, no more and no less.

RETIREMENT OF DEBT—the termination of a debt obligation by appropriate settlement with lender — understood to be in full amount unless partial settlement is specified.

SALVAGE VALUE—a. the cost recovered or which could be recovered from a used property when removed, sold, or scrapped. A factor in appraisal of property value and in computing depreciation; b. the market value of a machine or facility at any point in time. Normally, an estimate of an asset's net market value at the end of its estimated life.

SINKING FUND—a. a fund accumulated by periodic deposits and reserved exclusively for a specific purpose, such as retirement of a debt or replacement of a property; b. a fund created by making periodic deposits (usually equal) at compound interest in order to accumulate a given sum at a given future time for some specific purpose.

STRAIGHT-LINE DEPRECIATION—method of depreciation whereby the amount to be recovered (written off) is spread uniformly over the estimated life of the asset in terms of time periods or units of output. May be designated *percent of initial value*.

STUDY PERIOD—in economy study, the length of time that is presumed to be covered in the schedule of events and appraisal of results. Often the anticipated life of the project under consideration, but a shorter time may be more appropriate for decision making.

SUM-OF-DIGITS METHOD—also known as sum-of-the-years-digits method. A method of computing depreciation in which the amount for any year is based on the ratio: (years of remaining life)/(1 + 2 + 3 ... + N), N being the total anticipated life.

SUNK COST—a. the unrecovered balance of an investment. It is a cost, already paid, that is not relevant to the decision concerning the future that is being made. Capital already invested that for some reason cannot be retrieved; b. a past cost which has no relevance with respect to future receipts and disbursements of a facility undergoing an engineering economy study. This concept implies that since a past outlay is the same regardless of the alternative selected, it should not influence the choice between alternatives.

TIME VALUE OF MONEY—a. the cumulative effect of elapsed time on the money value of an event, based on the earning power of equivalent invested funds (see *Future Worth* and *Present Worth*); b. the expected interest rate that capital should or will earn.

WORKING CAPITAL—a. that portion of investment represented by *current assets* (assets that are not capitalized) less the *current liabilities*. The capital necessary to sustain operations; b. those funds that are required to make the enterprise or project a going concern.

Appendix B

BASIS AND CERTAIN FEATURES OF THE DISCOUNT TECHNIQUE*

D. R. Vondy

If the past history of all outlays of money and revenue were available for a company, it would be simple to display an economic picture for the period. Given a set of ground rules and assumed conditions, a similar display can be made for the future history of a proposed operation. The discounted worth method of economic analysis eliminates the time dependence of each contributing cost or revenue from this type of analysis and thereby reduces it to a simple balance without need for trial-and-error calculation. This discussion presents a simplified derivation of the discount equations applicable to economic analysis of a private electric utility and explains certain methods of calculation employed in this study.

It is assumed that revenue from an investment over a certain period will retire all associated indebtedness, as well as cover all costs. In actual practice, the services of a utility company normally increase with time, so there is not really retirement of debt because new investments are made that bring about a total increase in debt. Thus, "retirement of debt" actually means "freeing the money for new investment," but this does not alter the calculation. It is assumed that the indebtedness is in a fixed ratio of stock to bonds and that interest on bonds is tax deductible, while return on stock is not; a fixed ratio of indebtedness is realistic when only a fraction of a company's operation is to be examined.

While careful consideration is given here to the payment of income tax, there are many complications, such as local taxes, that are avoided to preserve clarity. The less favorable sinking-fund method of depreciation and the more favorable sum-of-the-digits method add complexity; the more elementary straight-line method (fixed periodic depreciation) is used. It should not be interpreted that these factors which are

*From M. W. Rosenthal et al., *A Comparative Evaluation of Advanced Converters*, ORNL-3686 (January 1965), pp. 243–48.

avoided are not important or that they cannot be handled; they are omitted only for simplification. In the analysis, "operating costs" are those that are immediately tax deductible, whereas "investment" or "capitalized expenditures" are those that can be deducted only as they are depreciated.

Income and outlay are assumed to occur at the end of each accounting period. There will be an outstanding debt at the end of each period that is to be eliminated at the end of the history. The unit price of electricity required to retire this debt is taken as constant over the plant life.

The following list defines symbols used for an accounting period n:

$Q(n)$ = amount of energy sold during period,

$Y(n)$ = outstanding indebtedness before considering income and outlays during period,

$Z(n)$ = investment (capitalized expenditure),

$V(n)$ = income from other than energy sale,

$D(n)$ = depreciation,

$O(n)$ = deductible operating costs,

$T(n)$ = income taxes,

$R(n)$ = net retirement income after costs and taxes,

C = direct cost before interest,

I = interest charge, which includes real cost of indebtedness and taxes,

P = unit selling price of energy to return all investment costs,

X = discount factor defined by the development,

N = history life,

r = tax rate on taxable income,

i = required return on stock,

j = required return on bonds,

b = fractional indebtedness in bonds,

m = fixed charge or interest on an investment.

Income tax is given by the applicable fraction of taxable income:

$$T(n) = r[PQ(n) - D(n) - O(n) - jbY(n)] \ . \qquad (B.1)$$

Net income is that remaining after costs:

$$R(n) = PQ(n) + V(n) - O(n) - [jb + i(1 - b)]\ Y(n) - T(n)$$

$$= (1 - r)\ PQ(n) + V(n) - (1 - r)\ O(n) + rD(n)$$

$$- [j(1 - r)b + i(1 - b)]\ Y(n)\ . \qquad \text{(B.2)}$$

Reduction in the outstanding debt is achieved by applying net income:

$$Y(n + 1) = Y(n) + Z(n) - R(n)\ ,$$

$$= [1 + j(1 - r)b + i(1 - b)]\ Y(n) + Z(n)$$

$$- (1 - r)\ PQ(n) - V(n) + (1 - r)\ O(n) - rD(n)\ . \qquad \text{(B.3)}$$

Equation (B.3) is one of recurrence in the outstanding debt. Recognizing the terms other than Y to be independent of Y, it may be simplified to

$$Y(n + 1) = (1 + X)\ Y(n) + A(n)\ , \qquad \text{(B.4)}$$

where

$$X = j(1 - r)b + i(1 - b)\ . \qquad \text{(B.5)}$$

For an initial investment and indebtedness of $Y(1) = Z(0)$, the solution to Eq. (B.4) is given by the expression

$$Y(a) = \sum_{n=0}^{n=a-1} (1 + X)^{a-n-1}\ A(n)\ ,$$

and retiring all indebtedness, $Y(N + 1) = 0$, is given by the expression

$$\sum_{n=0}^{N} (1 + X)^{N-n}\ A(n) = 0\ . \qquad \text{(B.6)}$$

In terms of the primary variables, the solution is given by

$$\sum_{n=0}^{N} (1 + X)^{N-n} [Z(n) - (1 - r)\ PQ(n) - V(n)$$

$$+ (1 - r)\ O(n) - rD(n)] = 0\ . \qquad \text{(B.7)}$$

The solution of Eq. (B.7) for an unknown unit selling price of energy is

$$P = \frac{\displaystyle\sum_{n=0}^{N} (1 + X)^{N-n} \left[\frac{Z(n) - V(n)}{(1 - r)} + O(n) - \frac{r}{1 - r}\ D(n)\right]}{\displaystyle\sum_{n=1}^{N} (1 + X)^{N-n}\ Q(n)}\ . \qquad \text{(B.8)}$$

Equation (B.7) discounts all items to the end of the history, that is, future value discounting; it is generally more flexible to work with present-value discounting, which is obtained by multiplying the numerator and denominator of Eq. (B.8) by $(1 + X)^{-N}$:

$$P = \frac{\displaystyle\sum_{n=0}^{N} (1 + X)^{-n} \left[\frac{Z(n) - V(n)}{(1 - r)} + O(n) - \frac{r}{1 - r}\ D(n)\right]}{\displaystyle\sum_{n=1}^{N} (1 + X)^{-n}\ Q(n)}\ ; \qquad \text{(B.9)}$$

at the beginning of reactor life,

$$D(0) = O(0) = Q(0) = 0\ .$$

The denominator may be interpreted as the present amount of power, and if $Q(n)$ is independent of n, it is the present value of an annuity. The factor X is the discount factor given in this simplified analysis by required returns, tax rate, and indebtedness split; it may be interpreted as the interest charge on outstanding debt after taking into consideration that bond payments are deductible, as indicated in Eq. (B.5):

$$X = j(1 - r)b + i(1 - b)\ .$$

For example, if $r = 0.48$ and $b = 0.67$, $X = 0.35j + 0.33i$; for $j = 0.045$ and $i = 0.09$, $X = 0.045$. The required return on investment for a number of depreciation methods based on annual accounting is presented in Fig. B.1 as dependent on the discount factor X; certain contributions that add directly to the required return, such as local taxes, insurance, and replacement, are not included.

The discount factor given by Eq. (B.9) may be compared with the "cost of money" factor, $jb + i(1 - b)$. Thus the true discount factor is less than the cost of money by an amount rjb. This may be explained by the fact that payments on bond indebtedness are tax deductible, and any increase in the ratio of bond to equity capital effectively lowers the discount factor. Use of a discount factor other than that given by Eq. (B.9), moreover, will not give the correct present value of future expenses and receipts.

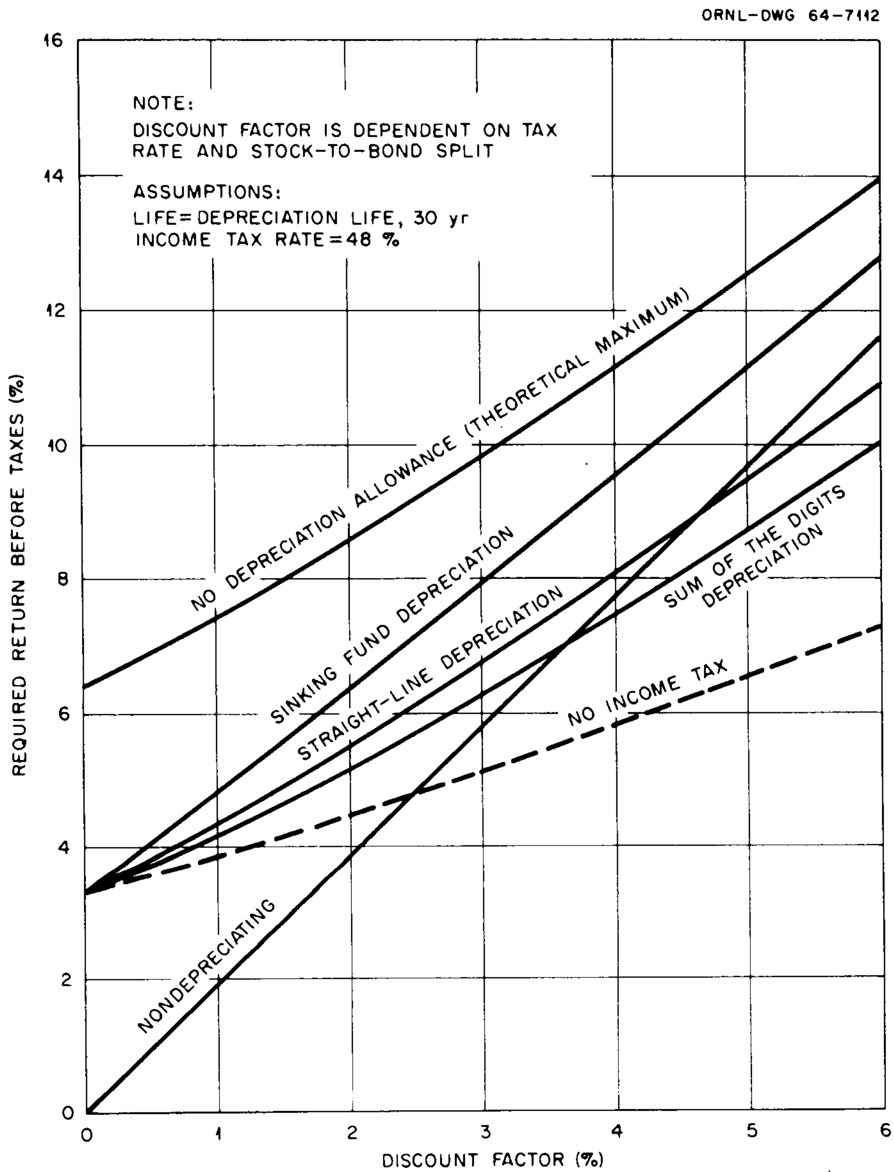


Fig. B.1. Return required on capital investment.

Appendix C

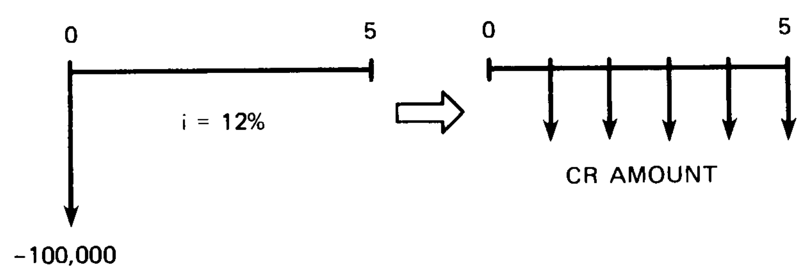
INTERPRETATION OF CAPITAL RECOVERY COSTS

The capital recovery factor arises from a concept having its origin in the mathematics of finance. It is a fraction that, when multiplied by a capital investment, provides a uniform annual payment necessary to recover the investment plus interest over a specified period of time (N). The annual capital recovery (CR) amount consists of depreciation determined by any acceptable method *and* interest on the unrecovered investment, which is calculated at the return expected by stockholders (here denoted by i). A *uniform* capital recovery amount is a levelized equivalent of a series of annual CR amounts (levelized at i).

A CR factor is a function of the average cost of capital and the specified time interval. The standard notation and formula for the CR factor are

$$(A/P,\ i,\ N) = \frac{i(1+i)^N}{(1+i)^N - 1} \ . \qquad (C.1)$$

To demonstrate the use of this formula, suppose that it is desired to convert a capital investment of \$100,000 into an equal uniform annual capital recovery amount over five years at 12% interest. Graphically, we wish to accomplish the following:



The CR amount above is equal to —\$100,000 (A/P, 12%, 5), or

$$CR = -\$100{,}000 \left[\frac{0.12(1.12)^5}{(1.12)^5 - 1}\right] = -\$27{,}741 \ .$$

(Note that the CR amount is *not* equal to —\$100,000/5.)

The uniform annual CR amount as calculated above can be easily verified by resorting to the definition given in the first paragraph above; that is,

$$CR_n = \text{depreciation}_n + i\ (\text{unrecovered investment})_n \ , \tag{C.2}$$

where $1 \leqslant n \leqslant N$. The following table is used to verify the calculation above, with depreciation in year n determined by the sum-of-the-years digits method:

Beginning of year n	Depreciation	Investment unrecovered at beginning of year n	Investment unrecovered × 12%	CR amount
1	$ 33,000	$100,000	$12,000	$45,333
2	26,667	66,667	8,000	34,667
3	20,000	40,000	4,800	24,800
4	13,333	20,000	2,400	15,733
5	6,667	6,667	800	7,467
	$100,000			

The annual CR amounts in the last column must now be converted to their *uniform* (levelized) value:

$$CR = [-45{,}333\ (P/F,\ 12\%,\ 1) - 34{,}667\ (P/F,\ 12\%,\ 2)$$

$$- \ldots - 7467\ (P/F,\ 12\%,\ 5)]\ (A/P,\ 12\%,\ 5) = -\$27{,}741\ .$$

This is identical to what was obtained with the standard formula.

Thus it can be seen that the CR amount "recovers" depreciation each year such that a capital asset can be replaced at the end of N years (no inflation), and it further takes into account the opportunity cost (lost interest) of having money tied up in the asset rather than in a bank earning i% interest each year. Revenues generated by the asset must be sufficient to cover the CR cost, plus other annual expenses such as materials, labor, maintenance, fuel, and income taxes. One last observation is that the present worth of a series of CR amounts, which include depreciation, equals the original investment. That is, −$27,741 (P/A, 12%, 5) = −$100,000.

Appendix D

GENERALIZED EQUATIONS FOR THE EQUIVALENCE OF THE REVENUE REQUIREMENT METHOD AND THE PRESENT-WORTH METHOD

The general equivalence of discounted cash flow analysis (with the present-worth method) and the revenue requirement method can be demonstrated in terms of several equations presented in Sects. 3 and 4. All equations are based on the assumption of zero salvage value and an effective income tax rate of 0.50. When t_e is not equal to 0.50, equivalence is tedious to show algebraically. However, for any reasonable value of t_e, equivalence of the PW method and the RR method *can be* demonstrated as was done in Tables 5 and 8.

If the annual RR, such as that developed in Table 5, is substituted into Table 8, the results of Table 9 are obtained. In Sect. 4 it was shown numerically that results of Table 5 are equivalent to those of Table 9. In both tables, income taxes computed at an effective rate of t_e [from Eq. (2)] are identical. This is true when revenues equaling the annual RR are inserted in an after-tax present-worth analysis with $t_e = 0.50$.

Based on the foregoing observation, *income taxes* calculated with each method in year n are equated so that general relationships between the PW method and the RR method can be established:

$$T = t_e(G - E - D_T - I) \ , \qquad \text{[see Eq. (3)]}$$

$$T = \frac{t_e}{1 - t_e}(f_E R_E + D_B - D_T) \ . \qquad \text{[see Eq. (13)]}$$

Thus,

$$t_e(G - E - D_T - I) = \frac{t_e}{1 - t_e}(f_E R_E + D_B - D_T) \ .$$

In general, the return to equity ($f_E R_E$) with the RR method equals the following when $f_E R_E$ represents the *dollar return* on unrecovered investment each year:

$$f_E R_E = (1 - t_e)(G - E - I) + t_e D_T - D_B \ . \tag{D.1}$$

(The term "I" represents interest paid in year n on the unpaid, beginning-of-year loan balance and equals $f_D R_D$, expressed in dollars.)

When tax depreciation is assumed to equal book depreciation, it is seen from Eq. (D.1) that

$$f_E R_E = (1 - t_e)(G - E - D - I) \ . \tag{D.2}$$

This relationship may be confirmed from Table 5 and Table 8 results. For example, in Table 5 the equity return in year 1 is \$9240, while from Table 8 the income taxes are $-0.5R + 26{,}340$ in year 1. When the RR in year 1 is substituted for R, income taxes equal \$9240 (this is true when $t_e = 0.5$).

In some economic analyses, revenues associated with proposed projects are (1) nonexistent (e.g., how best to generate process steam), or (2) assumed equal and thus ignored because of their commonality to all alternatives (e.g., various layouts for a new production line). A present-worth analysis of after-tax cash flows in such cases, designated PW-C analysis, produces numbers that are not obviously equivalent to a revenue requirement analysis of the same problem. However, by manipulation of Eqs. (3) and (13) this equivalence can be established. Specifically, it will be shown that income tax credits (savings) in Table 10 can be adjusted to produce the income tax liability calculated with the RR method for the same problem. Again, the same annual revenue is assumed common to both methods, except that it has been dropped from explicit consideration in a PW-C study, and the effective income tax rate is 50%.

By setting Eq. (3) equal to Eq. (13) and solving for the tax credit in a PW-C analysis, the following is obtained for year n:

$$\overbrace{t_e(E + D_T + I)}^{\text{tax credit}} = t_e G - \frac{t_e}{1 - t_e}(f_E R_E + D_B - D_T) \ . \tag{D.3}$$

The terms on the left are the positive tax credit present in a PW-C analysis of after-tax cash flow. It can be seen that this same tax credit is readily determined with information resulting from the RR method. Along similar lines, the income taxes in an RR study could be calculated from knowledge of the tax credit in a PW-C analysis:

$$\overbrace{\frac{t_e}{1 - t_e}(f_E R_E + D_B - D_T)}^{\text{income taxes}} = t_e G - \overbrace{t_e(E + D_T + I)}^{\text{tax credit}} \ . \tag{D.4}$$

When tax and book depreciation are equal, Eqs. (D.3) and (D.4) can be verified from results of example 2 (Table 5 compared with Table 10). In this case, Eq. (D.3) simplifies to

$$\text{tax credit (PW-C method)} = G(1 - t_e) - f_E R_E \ , \tag{D.5}$$

where G is the annual revenue requirement, and $f_E R_E$ is the return to equity, in dollars.

From Eq. (4), after-tax income in year n is defined to be

$$(G - E - D_T - I)(1 - t_e) \ ,$$

which also equals

$$\frac{-t_e}{1 - t_e}(f_E R_E + D_B - D_T) + (G - E - D_T - I) \ .$$

However, Eq. (5) states that after-tax income plus depreciation and loan repayment are equal to *after-tax* cash flow in year n. Hence, one can determine that this is valid:

$$\overbrace{[(G - E - D_T - I)\cdot(1 - t_e)] + D_T - P}^{\text{ATCF in PW analysis}} = (G - E - P - I)$$

$$- \frac{t_e}{1 - t_e}(f_E R_E + D_B - D_T) \ . \tag{D.6}$$

When revenues are omitted from a PW study, the resultant after-tax cash flow in year n can be determined from information available in an RR analysis, which is shown on the right-hand side of Eq. (D.7):

$$\overbrace{-(E + D_T + I)\cdot(1 - t_e) + D_T - P}^{\text{ATCF in PW-C analysis}} = (G - E - P - I) - G(1 - t_e)$$

$$- \frac{t_e}{1 - t_e}(f_E R_E + D_B - D_T) \ . \qquad \text{(D.7)}$$

When $D_B = D_T$ this relationship can again be verified with the results of Tables 5 and 10, where P = —$5250/year.

One last observation regarding the equivalence of the PW and the RR methods can be based on Eq. (D.6):

$$G(1 - t_e) = G - t_e(E + D_T + I) - \frac{t_e}{1 - t_e}(f_E R_E + D_B - D_T) \ .$$

When $D_B = D_T$,

$$G(\text{the revenue requirement}) = E + \overbrace{D + I + \frac{R_E f_E}{1 - t_e}}^{\text{carrying charge}} \ . \qquad \text{(D.8)}$$

In Eq. (D.8),

$$\frac{f_E R_E}{1 - t_e} = f_E R_E + T \ ,$$

and $(D - I + f_E R_E + T)$ is the carrying charge in year n on the capital investment [compare Eq. (D.8) with Eq. (11) when $I = f_D R_D$]. Thus, the revenue requirement equals the carrying charge on capital investment plus annual expenses [see Eq. (9)]. It is possible to start with after-tax cash flow as formulated by Eq. (D.6) (with or without revenues included) and to show that it equals the annual revenue requirement when book depreciation and tax depreciation are equal.

Once the annual revenue requirement (which has been shown to correspond to after-tax cash flow) is known, the levelized RR can easily be computed at the firm's *after-tax* weighted cost of capital (i'). This quantity is the same as the before-tax annual revenues that result from the PW method of discounted cash flow analysis (e.g., see Table 8). Some utilities prefer to make economic comparisons among alternatives in terms of present worth of RR, which is equivalent to maximizing PW at R_E in a discounted cash flow analysis. After equivalence has been established, it is possible to use Eqs. (D.1) through (D.8) in determining corresponding quantities from one method to the other.

When complications such as accelerated income taxes, shortened tax lives, salvage values, and investment tax credits are considered, the two methods still produce equivalent results. However, the algebraic manipulations become very tedious, and no further demonstration of generalized equivalence will be undertaken in this report. Many complications such as those mentioned above are treated further through numerical examples in Sect. 6.

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