Engineering Economy

Chapter 5: Evaluating a Single Project

The objective of Chapter 5 is to discuss and critique contemporary methods for determining project profitability.

Proposed capital projects can be evaluated in several ways.

- Present worth (PW)
- Future worth (FW)
- Annual worth (AW)
- Internal rate of return (IRR)
- External rate of return (ERR)
- Payback period (generally not appropriate as a primary decision rule)

Minimum Attractive Rate of Return (MARR)

To be attractive, a capital project must provide a return that exceeds a minimum level established by the organization. This minimum level is reflected in a firm's Minimum Attractive Rate of Return (MARR).

Many elements contribute to determining the MARR.

- Amount, source, and cost of money available
- Number and purpose of good projects available
- Perceived risk of investment opportunities
- Type of organization

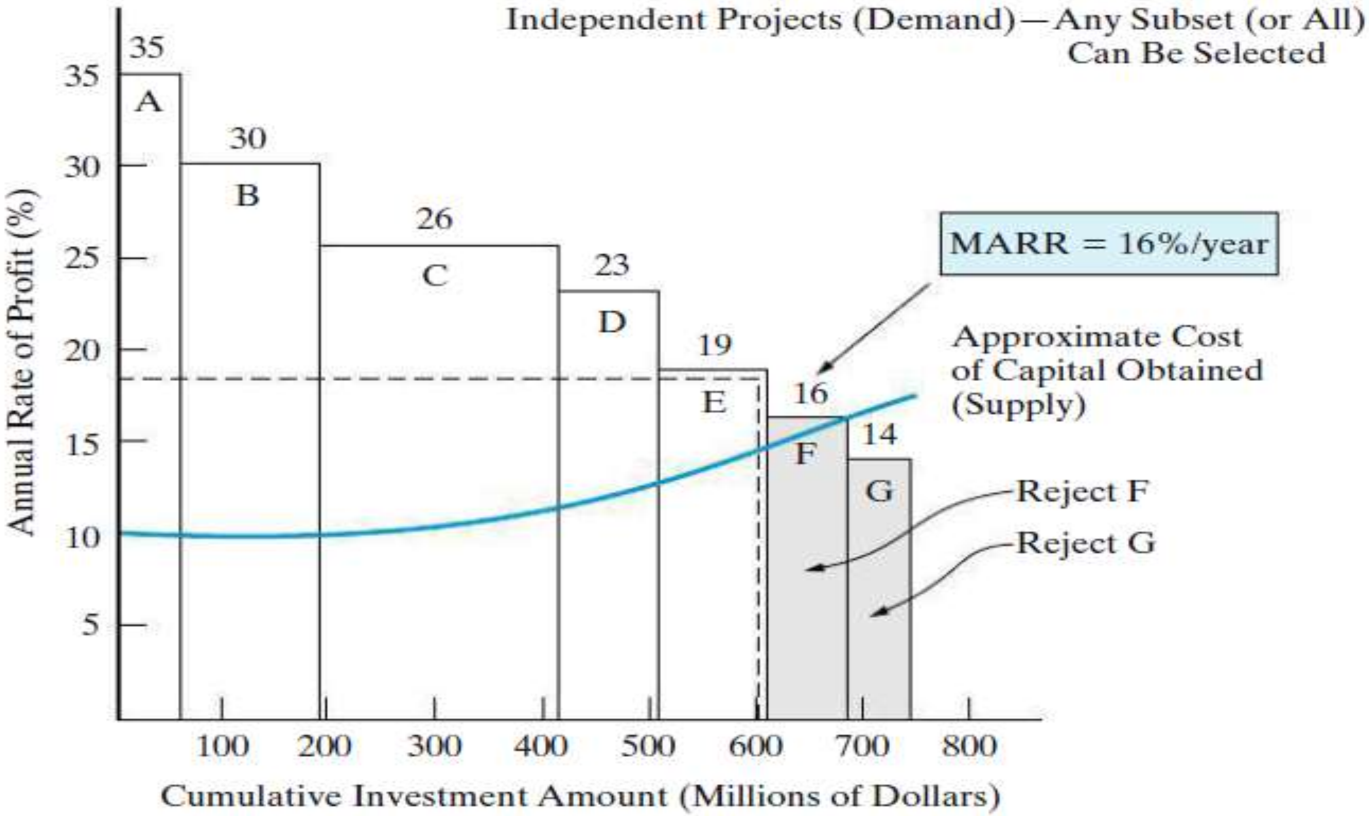


Figure 5-1 Determination of the MARR Based on the Opportunity Cost Viewpoint (A popular measure of annual rate of profit is "Internal Rate of Return," discussed later in this chapter.)

The most-used method is the Present Worth method.

The present worth (PW) is found by discounting all *cash inflows* and *outflows* to the present time at an interest rate that is generally the MARR.

A positive PW for an investment project means that the project is acceptable (it satisfies the MARR).

Present Worth Example

Consider a project that has an initial investment of $50,000 and that returns $18,000 per year for the next four years. If the MARR is 12%, is this a good investment?

$$PW = -50{,}000 + 18{,}000\,(P/A, 12\%, 4)$$

$$PW = -50{,}000 + 18{,}000\,(3.0373)$$

$PW = \$4{,}671.40$ → This is a good investment!

PW Example 5-1

Evaluation of New Equipment Purchase Using PW

A piece of new equipment has been proposed by engineers to increase the productivity of a certain manual welding operation. The investment cost is $25,000, and the equipment will have a market value of $5,000 at the end of a study period of five years. Increased productivity attributable to the equipment will amount to $8,000 per year after extra operating costs have been subtracted from the revenue generated by the additional production. A cash-flow diagram for this investment opportunity is given below. If the firm's MARR is 20% per year, is this proposal a sound one? Use the PW method.

Example 5-2

Present Worth of a Space-Heating System

A retrofitted space-heating system is being considered for a small office building. The system can be purchased and installed for $110,000, and it will save an estimated 300,000 kilowatt-hours (kWh) of electric power each year over a six-year period. A kilowatt-hour of electricity costs $0.10, and the company uses a MARR of 15% per year in its economic evaluations of refurbished systems. The market value of the system will be $8,000 at the end of six years, and additional annual operating and maintenance expenses are negligible. Use the PW method to determine whether this system should be installed.

PW Assumptions

- Future cash flows are known
- Future interest rate is known

Should we use it?

Bond value is a good example of present worth.

The commercial value of a bond is the PW of all future net cash flows expected to be received--the period dividend [face value (*Z*) times the bond rate (*r*)], and the redemption price (*C*), all discounted to the present at the bond's yield rate, *i%*.

$$V_N = C\,(P/F, i\%, N) + rZ\,(P/A, i\%, N)$$

Bond example

What is the value of a 6%, 10-year bond with a par (and redemption) value of $20,000 that pays dividends semi-annually, if the purchaser wishes to earn an 8% return?

$$V_N = \$20{,}000\ (P/F, 4\%, 20) + (0.03)\$20{,}000\ (P/A, 4\%, 20)$$

$$V_N = \$20{,}000\ (0.4564) + (0.03)\$20{,}000\ (13.5903)$$

$$V_N = \$17{,}282.18$$

Pause and solve

Bill Mitselfik wants to buy a bond. It has a face value of $50,000, a bond rate of 6% (nominal), payable semi-annually, and matures in 10 years. Bill wants to earn a nominal interest of 8%. How much should Bill pay for the bond?

Example 5-3

Stan Moneymaker Wants to Buy a Bond

Stan Moneymaker has the opportunity to purchase a certain U.S. Treasury bond that matures in eight years and has a face value of $10,000. This means that Stan will receive $10,000 cash when the bond's maturity date is reached. The bond stipulates a fixed nominal interest rate of 8% per year, but interest payments are made to the bondholder every three months; therefore, each payment amounts to 2% of the face value.

Stan would like to earn 10% nominal interest (compounded quarterly) per year on his investment, because interest rates in the economy have risen since the bond was issued. How much should Stan be willing to pay for the bond?

Capitalized worth (CW) is a special variation of present worth.

- Capitalized worth is the present worth of all revenues or expenses over an infinite length of time.
- If only expenses are considered this is sometimes referred to as *capitalized cost*.
- The capitalized worth method is especially useful in problems involving endowments and public projects with indefinite lives.

The application of CW concepts.

The CW of a series of end-of-period uniform payments A, with interest at *i%* per period, is $A(P/A, i\%, N)$. As N becomes very large (if the A are perpetual payments), the (P/A) term approaches $1/i$. So, $CW = A(1/i)$.

Pause and solve

Betty has decided to donate some funds to her local community college. Betty would like to fund an endowment that will provide a scholarship of $25,000 each year in perpetuity, and also a special award, "Student of the Decade," each ten years (again, in perpetuity) in the amount of $50,000. How much money does Betty need to donate today, in one lump sum, to fund the endowment? Assume the fund will earn a return of 8% per year.

Note: An endowment is a donation of money or property to a non-profit organization, which uses the resulting investment income for a specific purpose.

Future Worth (FW) method is an alternative to the PW method.

- Looking at FW is appropriate since the primary objective is to maximize the future wealth of owners of the firm.
- FW is based on the equivalent worth of all cash inflows and outflows at the end of the study period at an interest rate that is generally the MARR.
- Decisions made using FW and PW will be the same.

Future worth example.

A \$45,000 investment in a new conveyor system is projected to improve throughput and increasing revenue by \$14,000 per year for five years. The conveyor will have an estimated market value of \$4,000 at the end of five years. Using FW and a MARR of 12%, is this a good investment?

$$FW = -\$45,000(F/P, 12\%, 5)+\$14,000(F/A, 12\%, 5)+\$4,000$$

$$FW = -\$45,000(1.7623)+\$14,000(6.3528)+\$4,000$$

$FW = \$13,635.70$ → This is a good investment!

Example 5-1 with FW

Annual Worth (AW) is another way to assess projects.

- Annual worth is an equal periodic series of dollar amounts that is *equivalent* to the cash inflows and outflows, at an interest rate that is generally the MARR.
- The AW of a project is annual equivalent revenue or savings minus annual equivalent expenses, less its annual capital recovery (*CR*) amount.

$$AW(i\%) = \underline{R} - \underline{E} - CR(i\%)$$

Capital recovery reflects the capital cost of the asset.

- *CR* is the annual equivalent cost of the capital invested.
- The *CR* covers the following items.
  - Loss in value of the asset.
  - Interest on invested capital (at the MARR).
- The *CR* distributes the initial cost (*I*) and the salvage value (*S*) across the life of the asset.

$$CR(i\%) = I(A/P, i\%, N) - S(A/F, i\%, N)$$

A project requires an initial investment of $45,000, has a salvage value of $12,000 after six years, incurs annual expenses of $6,000, and provides an annual revenue of $18,000. Using a MARR of 10%, determine the AW of this project.

$$AW(10\%) = \underline{R} - \underline{E} - CR(10\%)$$

$$CR(10\%) = 45,000(A/P, 10\%, 6) - 12,000(A/F, 10\%, 6)$$

$$CR(10\%) = 8,777$$

$$AW(10\%) = 18,000 - 6,000 - 8,777 = \$3,223$$

Since the *AW* is positive, it’s a good investment.

Internal Rate of Return

- The internal rate of return (IRR) method is the most widely used rate of return method for performing engineering economic analysis.
- It is also called the *investor's method*, the *discounted cash flow* method, and the *profitability index*.
- If the IRR for a project is greater than the MARR, then the project is *acceptable*.

How the IRR works

- The IRR is the interest rate that equates the equivalent worth of an alternative's cash *inflows* (revenue, *R*) to the equivalent worth of cash *outflows* (expenses, *E*).
- The IRR is sometimes referred to as the *breakeven interest rate*.

The IRR is the interest *i'%* at which

$$\sum_{k=0}^{N} R_k(P/F, i'\%, k) = \sum_{k=0}^{N} E_k(P/F, i'\%, k)$$

Solving for the IRR is a bit more complicated than PW, FW, or AW

- The method of solving for the *i'%* that equates revenues and expenses normally involves trial-and-error calculations, or solving numerically using mathematical software.
- The use of spreadsheet software can greatly assist in solving for the IRR. Excel uses the *IRR(range, guess)* or *RATE(nper, pmt, pv)* functions.

Challenges in applying the IRR method.

- It is computationally difficult without proper tools.
- In rare instances multiple rates of return can be found. (See Appendix 5-A.)
- The IRR method must be carefully applied and interpreted when comparing two more mutually exclusive alternatives (e.g., do not directly compare internal rates of return).

Economic Desirability of a Project Using the IRR Method

AMT, Inc., is considering the purchase of a digital camera for the maintenance of design specifications by feeding digital pictures directly into an engineering workstation where computer-aided design files can be superimposed over the digital pictures. Differences between the two images can be noted, and corrections, as appropriate, can then be made by design engineers. The capital investment requirement is $345,000 and the estimated market value of the system after a six-year study period is $115,000. Annual revenues attributable to the new camera system will be $120,000, whereas additional annual expenses will be $22,000. You have been asked by management to determine the IRR of this project and to make a recommendation. The corporation's MARR is 20% per year. Solve first by using linear interpolation and then by using a spreadsheet.

Solution by Linear Interpolation

In this example, we can easily see that the sum of positive cash flows ($835,000) exceeds the sum of negative cash flows ($455,000). Thus, it is likely that a positive-valued IRR can be determined. By writing an equation for the PW of the project's total net cash flow and setting it equal to zero, we can compute the IRR:

$$\begin{aligned} PW = 0 &= -\$345{,}000 + (\$120{,}000 - \$22{,}000)(P/A, i'\%, 6) \\ &\quad + \$115{,}000(P/F, i'\%, 6) \\ i'\% &= ? \end{aligned}$$

To use linear interpolation, we first need to try a few values for i'. A good starting point is to use the MARR.

$$\begin{aligned} \text{At } i' = 20\%: \quad PW &= -\$345{,}000 + \$98{,}000(3.3255) + \$115{,}000(0.3349) \\ &= +\$19{,}413 \end{aligned}$$

Now that we have both a positive and a negative PW, the answer is bracketed ($20\% \leq i'\% \leq 25\%$). The dashed curve in Figure 5-5 is what we are linearly approximating. The answer, $i'\%$, can be determined by using the similar triangles represented by dashed lines in Figure 5-5.

$$\frac{\text{line BA}}{\text{line BC}} = \frac{\text{line dA}}{\text{line de}}.$$

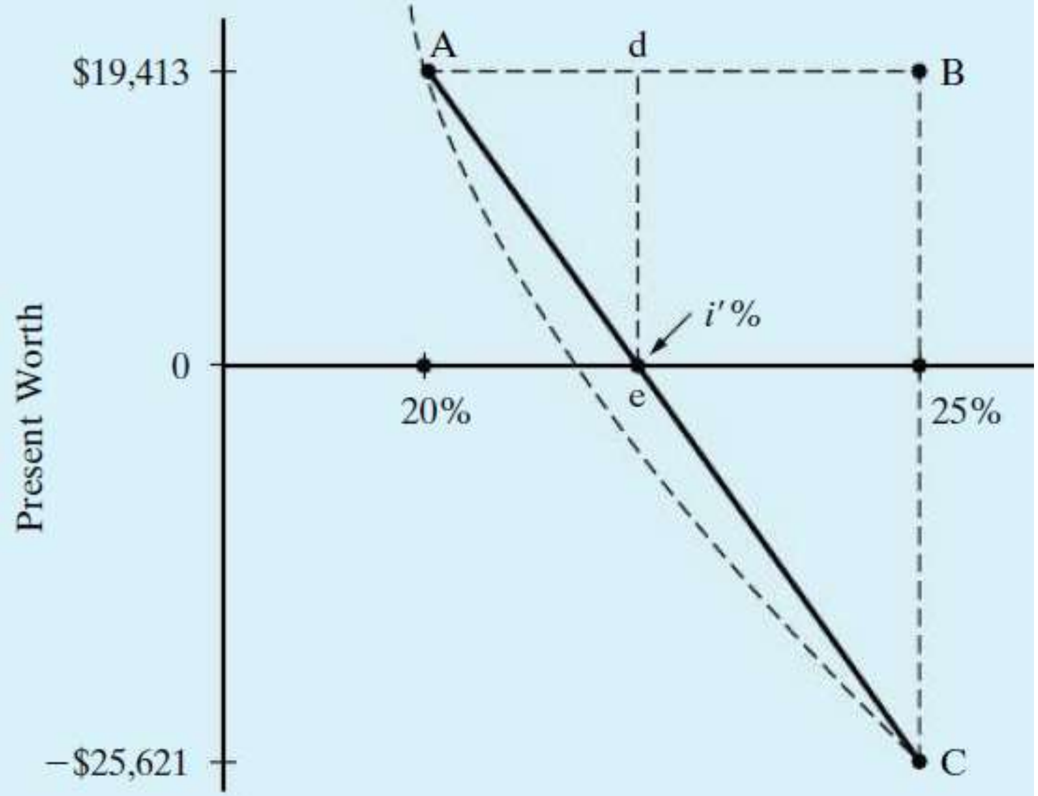
Here, BA is the line segment $B - A = 25\% - 20\%$. Thus,

$$\frac{25\% - 20\%}{\$19{,}413 - (-\$25{,}621)} = \frac{i'\% - 20\%}{\$19{,}413 - \$0}$$

$$i' \approx 22.16\%.$$

Because the IRR of the project (22.16%) is greater than the MARR, the project is acceptable.

Figure 5-5 Use of Linear Interpolation to Find the Approximation of IRR for Example 5-12



Investment-Balance Diagram Showing IRR

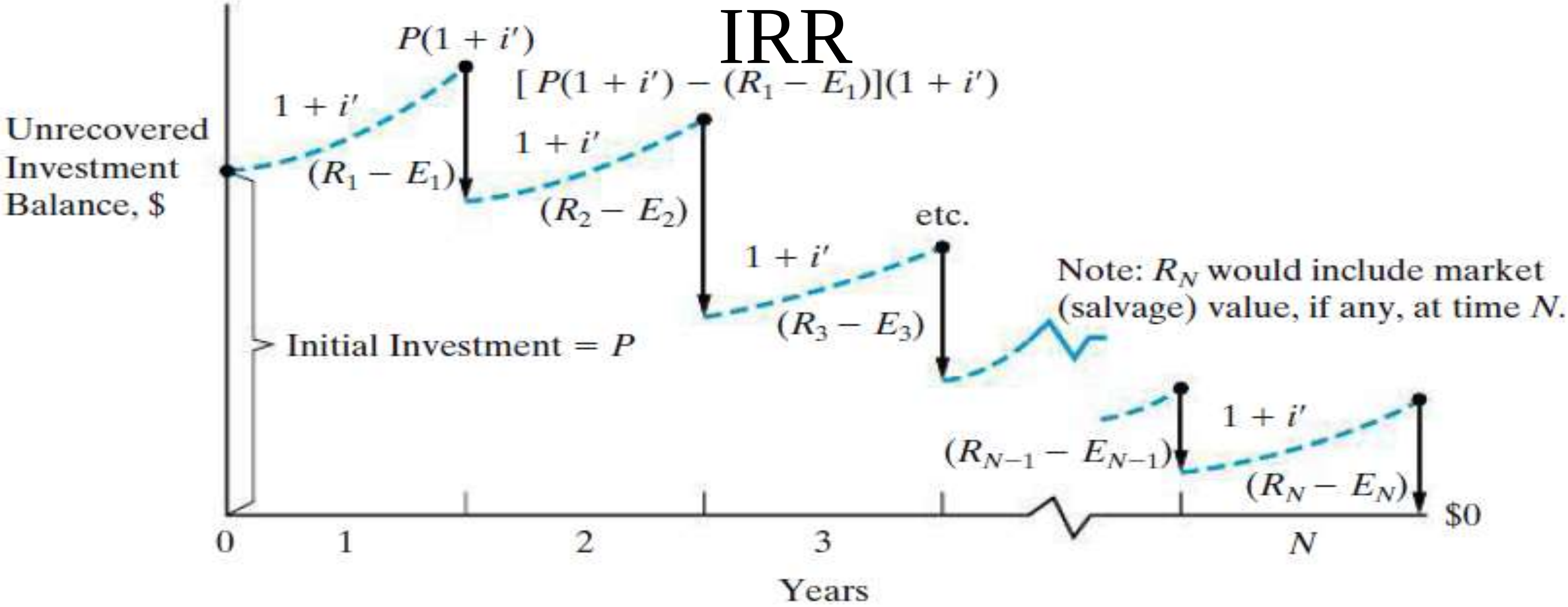
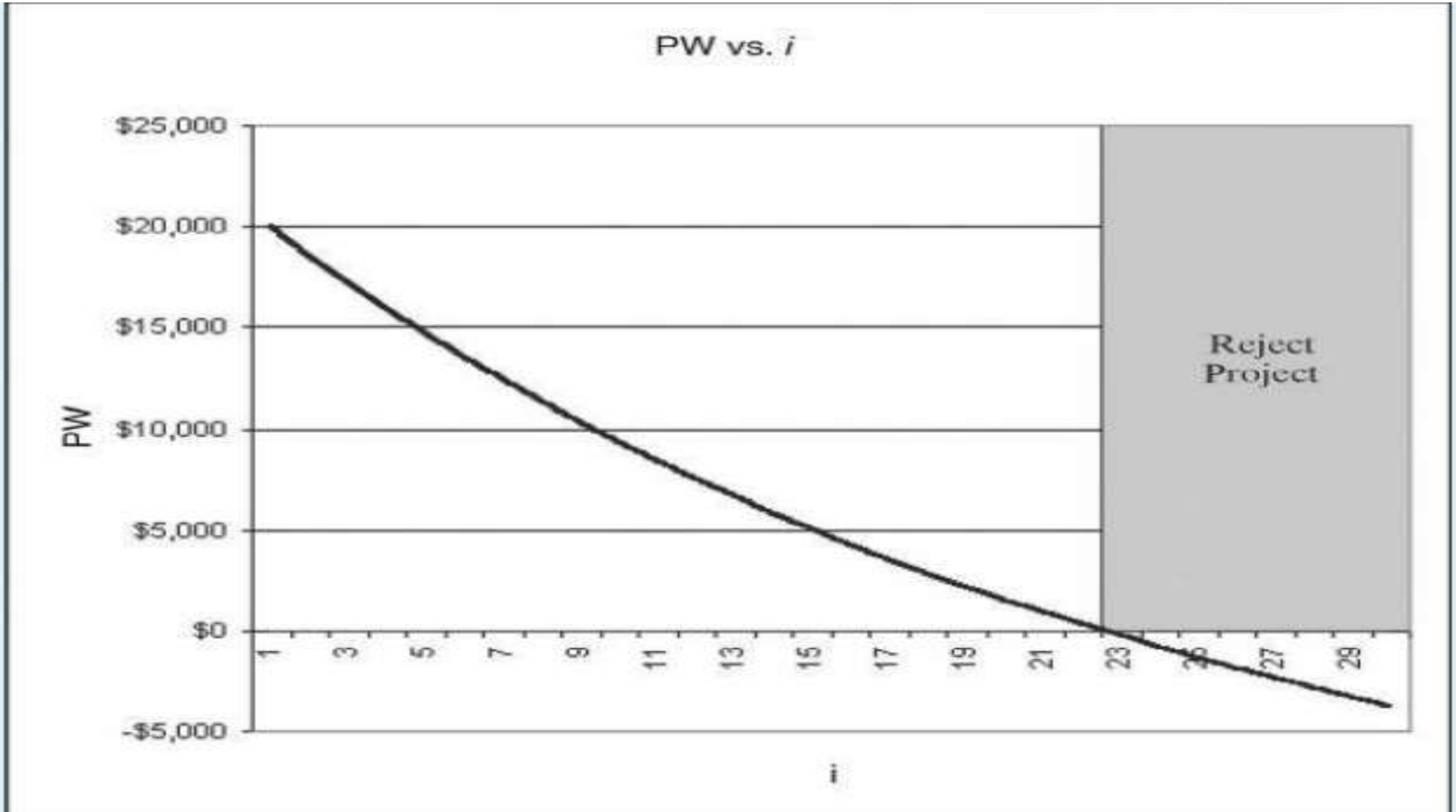


Figure 5-4 Investment-Balance Diagram Showing IRR

Example 5-13

Evaluation of New Equipment Purchase, Using the Internal Rate of Return Method (Example 5-1 Revisited)

A piece of new equipment has been proposed by engineers to increase the productivity of a certain manual welding operation. The investment cost is $25,000, and the equipment will have a market (salvage) value of $5,000 at the end of its expected life of five years. Increased productivity attributable to the equipment will amount to $8,000 per year after extra operating costs have been subtracted from the value of the additional production. Use a spreadsheet to evaluate the IRR of the proposed equipment. Is the investment a good one? Recall that the MARR is 20% per year.



(b) Graphical Determination of IRR

Example 5-14

Do You Know What Your Effective Interest Rate Is?

In 1915, Albert Epstein allegedly borrowed $7,000 from a large New York bank on the condition that he would repay 7% of the loan every three months, until

a total of 50 payments had been made. At the time of the 50th payment, the $7,000 loan would be completely repaid. Albert computed his annual interest rate to be $[0.07(\$7{,}000) \times 4]/\$7{,}000 = 0.28$ (28%).

(a) What true *effective* annual interest rate did Albert pay?

(b) What, if anything, was wrong with his calculation?

Reinvesting revenue—the External Rate of Return (ERR)

- The IRR assumes revenues generated are reinvested at the IRR—which may not be an accurate situation.
- The ERR takes into account the interest rate, ε, external to a project at which net cash flows generated (or required) by a project over its life can be reinvested (or borrowed). This is usually the MARR.
- If the ERR happens to equal the project's IRR, then using the ERR and IRR produce identical results.

The ERR procedure

- Discount all the net cash *outflows* to time *0* at ε% per compounding period.
- Compound all the net cash *inflows* to period *N* at at ε%.
- Solve for the ERR, the interest rate that establishes equivalence between the two quantities.

ERR is the *i'%* at which

$$\sum_{k=0}^{N} E_k(P/F, \varepsilon\%, k)(F/P, i'\%, N) = \sum_{k=0}^{N} R_k(F/P, \varepsilon\%, N-k)$$

where

R_k = excess of receipts over expenses in period k,
E_k = excess of expenses over receipts in period k,
N = project life or number of periods, and
ε = external reinvestment rate per period.

Applying the ERR method

For the cash flows given below, find the ERR when the external reinvestment rate is ε = 12% (equal to the MARR).

Year	0	1	2	3	4
Cash Flow	-$15,000	-$7,000	$10,000	$10,000	$10,000

Expenses $15,000 + 7,000(P/F, 12\%, 1) = 21,250$

Revenue $10,000(F/A, 12\%, 3) = 33,744$

Solving, we find

$$21,250(F/P, i'\%, 4) = 33,744$$

$$i' = 16.67\% > 12\%$$

The payback period method is simple, but possibly misleading.

- The simple payback period is the number of years required for cash *inflows* to just equal cash *outflows*.
- It is a measure of *liquidity* rather than a measure of profitability.

Payback is simple to calculate.

The payback period is the *smallest* value of θ ($\theta \leq N$) for which the relationship below is satisfied.

$$\sum_{k=1}^{\theta}(R_k - E_k) - I \geq 0$$

For *discounted* payback future cash flows are discounted back to the present, so the relationship to satisfy becomes

$$\sum_{k=1}^{\theta'}(R_k - E_k)(P/F, i\%, k) - I \geq 0$$

Problems with the payback period method.

- It doesn't reflect any cash flows occurring after θ, or θ'.
- It doesn't indicate anything about project desirability except the speed with which the initial investment is recovered.
- Recommendation: use the payback period only as supplemental information in conjunction with one or more of the other methods in this chapter.

Example 5-1/5-13

- Use payback period and discounted payback period.

Example 5-1 by Nominal Interest Rate

$$\text{PW}(\underline{r} = 20\%) = -\$25{,}000 + \$8{,}000(P/A, \underline{r} = 20\%, 5)$$

$$+\$5{,}000(P/F, \underline{r} = 20\%, 5)$$

$$= -\$25{,}000 + \$8{,}000(2.8551) + \$5{,}000(0.3679)$$

$$= -\$319.60.$$

Finding the simple and discounted payback period for a set of cash flows.

The cumulative cash flows in the table were calculated using the formulas for simple and discounted payback.

From the calculations $\theta = 4$ years and $\theta' = 5$ years.

End of Year	Net Cash Flow	Cumulative PW at *0%*	Cumulative PW at *6%*
0	-$42,000	-$42,000	-$42,000
1	$12,000	-$30,000	-$30,679
2	$11,000	-$19,000	-$20,889
3	$10,000	-$9,000	-$12,493
4	$10,000	$1,000	-$4,572
5	$9,000		$2,153

Thank You