



# Standard Practice for Measuring Internal Rate of Return and Adjusted Internal Rate of Return for Investments in Buildings and Building Systems<sup>1</sup>

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## INTRODUCTION

The internal rate-of-return (IRR) and adjusted internal rate-of-return (AIRR) methods are members of a family of economic evaluation methods that provide measures of economic performance of an investment over time. Other methods in this family of evaluation methods are life-cycle cost analysis, net benefits analysis, benefit-to-cost and savings-to-investment ratio analysis, and payback analysis.

The IRR and AIRR methods are the topic of a single standard practice because they both measure economic performance as a compound yield on investment. The IRR is the compound rate of interest that, when applied as a discount rate to a project's stream of dollar benefits and costs, will equate them. The AIRR is the overall yield taking into account earnings on receipts reinvested to the end of the study period. The IRR or AIRR is compared against the investor's minimum acceptable rate of return (MARR), and the investment is considered economically attractive if the calculated yield exceeds the MARR. If an investment entails an initial outlay and a single receipt at the end of the study period, there is no difference between the IRR and the AIRR. But if cash flows occur over multiple time periods, the two will normally be different. This arises because the AIRR includes in its measure the return on reinvestment of receipts, whereas the IRR does not.

The AIRR is recommended for most applications in which a measure of yield is desired. Caution is recommended in applying either measure, however, because problems arise under certain conditions.

## 1. Scope

1.1 This practice establishes a procedure for calculating and interpreting the IRR and AIRR measures in the evaluation of building designs, systems, and equipment.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- E 833 Terminology of Building Economics<sup>2</sup>
- E 917 Practice for Measuring Life-Cycle Costs of Buildings and Building Systems<sup>2</sup>
- E 964 Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for Buildings and Building Systems<sup>2</sup>
- E 1074 Practice for Measuring Net Benefits for Investments in Buildings and Building Systems<sup>2</sup>
- E 1121 Practice for Measuring Payback for Investments in

### Buildings and Building Systems<sup>2</sup>

E 1185 Guide for Selecting Economic Methods for Evaluating Investments in Buildings and Building Systems<sup>2</sup>

### 2.2 ASTM Adjuncts:

- Discount Factor Tables*, Adjunct to Practices E 917, E 964, E 1057, and E 1074<sup>3</sup>
- Computer Program and User's Guide to Building Maintenance, Repair, and Replacement Database for Life-Cycle Cost Analysis*, Adjunct to Practices E 917, E 964, E 1057, E 1074, and E 1121<sup>4</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology E 833.

## 4. Summary of Practice

4.1 This practice is organized as follows:

4.1.1 *Section 1, Scope*—Identifies coverage.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.11.

<sup>3</sup> Available from ASTM Headquarters. Order PCN 12-509170-10.

<sup>4</sup> Available from ASTM Headquarters. Order PCN 12-509171-10 for the 3.5 in. disk. Order PCN 12-509172-10 for the 5.25 in. disk.

4.1.2 *Section 2, Applicable Documents*—Lists ASTM standards that are referenced.

4.1.3 *Section 3, Terminology*—Addresses definitions of terms.

4.1.4 *Section 4, Summary of Practice*—Outlines the contents.

4.1.5 *Section 5, Significance and Use*—Explains the relevance of the IRR and AIRR and indicates their appropriate uses.

4.1.6 *Section 6, Procedures*—Summarizes the steps in IRR and AIRR analysis.

4.1.7 *Section 7, Objectives, Constraints, and Alternatives*—Discusses the first step in an analysis, that is, the identification of the objectives of the analysis, any constraints that must be taken into account in finding a solution, and technically feasible project alternatives.

4.1.8 *Section 8, Data and Assumptions*—Discusses the second step in an analysis; that is the data and assumptions that are typically required for calculating the IRR and AIRR, and, in particular, the requirement of the AIRR for specification of a reinvestment rate.

4.1.9 *Section 9, IRR Calculation*—Describes the third step, performing calculations, as it applies to the IRR.

4.1.10 *Section 10, AIRR Calculation*—Describes the third step, performing calculations, as it applies to the AIRR.

4.1.11 *Section 11, Choosing Between the IRR and AIRR*—Discusses how to choose between the IRR and the AIRR.

4.1.12 *Section 12, Limitations*—Discusses limitations and shortcomings of the IRR and AIRR.

4.1.13 *Section 13, Applications*—Describes the types of decisions to which the IRR and AIRR are applicable.

4.1.14 *Section 14, Report*—Identifies information that shall be included in a report of an IRR or AIRR application.

## 5. Significance and Use

5.1 The IRR method has been used traditionally in finance and economics to measure the percentage yield on investment.

5.1.1 The IRR method is appropriate in most cases for evaluating whether a given building or building system will be economically efficient, that is, whether its time-adjusted benefits will exceed its time-adjusted costs over the period of concern to the decision maker. However, it has deficiencies that limit its usefulness in choosing among projects competing for a limited budget.

5.2 The AIRR method is a measure of the overall rate of return that an investor can expect from an investment over a designated study period. It is appropriate both for evaluating whether a given building or building system will be economically efficient and for choosing among alternatives competing for a limited budget.

5.2.1 The AIRR method overcomes some, but not all, of the deficiencies of the IRR. The AIRR is particularly recommended over the IRR for allocating limited funding among competing projects.

## 6. Procedure

6.1 The recommended steps for applying the IRR or the AIRR method to an investment decision are summarized as follows:

6.1.1 Identify objectives, constraints, and alternatives.

6.1.2 Compile data.

6.1.3 Compute IRR or AIRR based on a comparison of two alternatives (one of which may be to do nothing).

6.1.4 Compare the computed IRR or AIRR against the MARR to determine the acceptability of the alternative with the higher investment cost.

6.1.5 If a limited budget is to be allocated among competing alternatives, select alternatives in descending order of their IRR or AIRR measures until the budget is exhausted.

6.1.6 Report the results.

## 7. Objectives, Constraints, and Alternatives

7.1 Specify clearly the objective of the economic analysis.

7.1.1 Suppose, for example, an individual or organization has funds on hand to invest in real estate projects. The problem is which projects to choose from potential candidates. The objective of the economic analysis in this case is to identify the project or set of projects within the budget that is expected to maximize profits over the long run.

7.2 Identify any constraints that narrow the field of candidates.

7.2.1 Constraints, for example, might include a budget of \$1 000 000; a geographical limitation to buildings located within 100 km from downtown; and a strong preference for nonresidential property.

7.3 Identify feasible alternatives.

7.3.1 Feasible alternatives include an office building in the suburbs costing \$1 000 000; convenience shopping strips in nearby towns costing a total of \$900 000; two medical/dental offices costing \$500 000 each; and a \$1 000 000 investment share in a downtown shopping complex.

## 8. Data

8.1 To calculate the IRR or AIRR, data are needed. The microcomputer program database and adjunct user's guide are helpful in estimating maintenance, repair, and replacement costs.

8.2 Benefit and cost data that are often relevant when calculating the IRR or AIRR are revenues, resale or salvage value, subsidies (for example, grants), and costs of planning, design, engineering, construction, purchase, installation, operation and maintenance, utilities, and repairs and replacement.

8.3 The time of occurrence of each benefit and cost is also needed.

8.4 Taxes such as tax credits, property taxes, and income taxes are also often relevant because they affect benefits and costs. If benefits and costs are adjusted for taxes, the IRR or AIRR measure gives the *after-tax* rate of return.

8.5 If the terms of financing are unique to each alternative, financing costs (and associated tax effects) should also be taken into account.

8.6 Choose a minimum acceptable rate of return (MARR) for comparison against the calculated IRR or AIRR.

8.6.1 The appropriate MARR indicates the investor's opportunity cost of foregoing the return on the next best investment opportunity in order to invest in the project in question.

8.7 If the AIRR is used, a reinvestment rate is needed.

**TABLE 1 Trial-and-Error Solution for Internal Rate of Return**

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Year (t)	Benefits (B <sub>t</sub> )	Costs (C <sub>t</sub> )	Net Cash Flow (B <sub>t</sub> - C <sub>t</sub> ) (4) = (2) - (3)	SPV Factor for i = 25 %	PVNB at 25 % (6) = (4) × (5)	SPV Factor for i = 22 %	PVNB at 22 % (8) = (4) × (7)
0	0	\$10 000	\$-10 000	1.000	\$-10 000	1.000	\$-10 000
1	\$ 4 000	3 000	1 000	0.8000	800	0.8197	820
2	11 500	4 500	7 000	0.6400	4 480	0.6719	4 703
3	10 000	4 000	6 000	0.5126	3 076	0.5507	3 304
4	8 000	5 000	3 000	0.4096	1 229	0.4514	1 354
Total			\$7 000		\$-415		\$181

8.7.1 The reinvestment rate is usually set equal to the MARR; hence, it equals the discount rate. This is because the reinvestment rate is an indicator of future opportunity cost, and that is also the purpose of the discount rate. Setting the reinvestment rate and the discount rate equal makes the reinvestment rate assumption in the AIRR method consistent with the reinvestment rate assumption that is implicit in the net benefits method (Practice E 1074).

## 9. IRR Calculation

9.1 The IRR is the compound rate of interest that, when used to discount a project's cash flows, will reduce the present value of net benefits (PVNB) to zero. (See Practice E 1074 for a discussion of how to compute the PVNB.) The solution value of  $i^*$  in Eq 1 is the IRR. It is computed as a decimal, then expressed as a percent.

9.1.1 Find the value of  $i^*$  for which:

$$PVNB = \sum_{t=0}^N (B_t - \bar{C}_t)/(1 + i^*)^t = 0 \quad (1)$$

where:

PVNB = present value of net benefits (or, if applied to a cost-reducing investment, present value of net savings),

$N$  = number of discounting periods in the study period,  
 $B_t$  = dollar value of benefits in period t for the building or system evaluated less the counterpart benefits in period t for the mutually exclusive alternative against which it is compared,

$\bar{C}_t$  = dollar costs, including investment costs, in period t for the building or system evaluated less the counterpart costs in period t for the mutually exclusive alternative against which it is compared, and

$i^*$  = interest rate for which PVNB = 0, that is, the IRR measure expressed as a decimal.

9.2 An algebraic solution of  $i^*$  is not possible with Eq 1 for all values of N. Use a computer program with built-in formulas to calculate IRR and AIRR. Or, use a manual approach to approximate the IRR such as the trial-and-error approach, the graphical approach, and an approach that uses simple payback and uniform present value (UPV) factor tables. (See Practice E 1121 for a description of payback and the Adjunct on Discount Factor Tables for UPV factors.)

9.2.1 *Trial and Error Solution:*

9.2.1.1 The trial-and-error approach to calculating the IRR entails choosing a trial rate of interest that is expected

approximately to balance benefits and costs over the project study period. Then present value calculations are made for that trial rate. (For an illustration of discounting calculations, see Practice E 917.) If the PVNB is zero, then the trial rate is the solution value of the internal rate of return. If the PVNB is negative, the trial rate is too high, and a second, lower trial rate is then used. If the PVNB is positive for the original trial rate, then the IRR is higher than the trial rate, and a second, higher trial rate is used. When two trial rates are found such that one yields a PVNB greater than zero and the other a PVNB less than zero, the IRR lies between those rates and can be approximated by interpolation, provided the investment has a unique IRR. Considerable time is saved in the trial-and-error approach if the first trial rate is close to the true rate. One approach is to start with the MARR as the trial rate. If the PVNB is negative with the MARR, then the project is not economically feasible, and no further calculations are necessary. If the PVNB is positive, then select higher trial rates in an attempt to bound the true rate.

9.2.1.2 The UPV factor tables are useful in finding a trial rate. The first step is to sum the undiscounted cash flows (not including the initial cost) and divide the sum by the number of years in the study period (excluding any planning/design/construction period) to obtain an average annual cash flow. Then divide the initial project cost by the average to obtain a rough estimate of simple payback (SPB). The second step is to search the UPV discount factor tables in the row that corresponds to the study period for the UPV factor that is closest to the estimated SPB. (Again exclude any years in the planning/design/construction period.) The rate that appears at the top of the column in which the UPV factor is found is a promising trial rate. The more uniform the annual cash flow, the more likely that this trial rate will be close to the solution rate.

9.2.1.3 Table 1 illustrates the trial-and-error approach for calculating the IRR for an initial investment that yields an uneven yearly cash flow over four years. Columns 2 and 3 list the dollar values of benefits and costs that accrue in each of the four years, and Column 4 shows the net cash flow for each of those years, including the initial investment.

9.2.1.4 From inspecting Column 4 in Table 1, one might expect a relatively high return over four years. Using the approach described in 9.2.1.2 to select a trial rate, the calculated UPV value for four years corresponds in the Adjunct discount tables most closely to a rate of 25 %. Multiplying yearly net cash flows by single present value (SPV) factors for each year based on a 25 % discount rate (Column 5) converts