



Standard Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for Buildings and Building Systems¹

This standard is issued under the fixed designation E 964; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

^{ε1} NOTE—Footnote 5 of this standard was editorially corrected in Sept 1998.

INTRODUCTION

This is one in a series of practices for applying economic evaluation methods to building-related decisions. Methods covered by this practice are benefit-to-cost ratio (BCR) and savings-to-investment ratio (SIR). These are members of a family of economic evaluation methods that can be used to measure the economic consequences of a decision over a specified period of time. The BCR is used when the focus is on benefits (that is, advantages measured in dollars) relative to project costs. The SIR, a variation of the BCR, is used when the focus is on project savings (that is, cost reductions) relative to project costs. The family of methods includes, in addition to BCR and SIR, net benefits, life-cycle cost, internal rate-of-return, adjusted internal rate-of-return, and payback (see Practices E 917, E 1057, E 1074, and E 1121). Guide E 1185 directs you to the appropriate method for a particular economic problem.

BCR and SIR are numerical ratios that indicate the economic performance of a project by the size of the ratio. A ratio less than 1.0 indicates a project that is uneconomic, a ratio of 1.0 indicates a project whose benefits or savings just equal its costs, and a ratio greater than 1.0 indicates a project that is economic. While it is straightforward to use ratios to determine whether a given project is economic or uneconomic, care must be taken to correctly interpret ratios when using them to choose among alternative designs and sizes of a project, or to assign priority to projects competing for limited funds.

1. Scope

1.1 This practice presents a procedure for calculating and interpreting benefit-to-cost ratios (BCR) and savings-to-investment ratios (SIR) as an aid for making building-related decisions.

1.2 A basic premise of the BCR and SIR methods is that future as well as present benefits and costs arising from a decision are important to that decision, and, if measurable in dollars, should be included in calculating the BCR and SIR.

1.3 Dollar amounts used to calculate BCR and SIR are all discounted, that is, expressed in time-equivalent dollars, either in present value or uniform annual value terms.

2. Referenced Documents

2.1 ASTM Standards:

E 833 Terminology of Building Economics²

E 917 Practice for Measuring Life-Cycle Costs of Buildings

and Building Systems²

E 1057 Practice for Measuring Internal Rate of Return and Adjusted Internal Rate of Return for Investments in Buildings and Building Systems²

E 1074 Practice for Measuring Net Benefits for Investments in Buildings and Building Systems²

E 1121 Practice for Measuring Payback for Investments in Building and Building Systems²

E 1185 Guide for Selecting Economic Methods for Evaluating Investments in Buildings and Building Systems²

2.2 ASTM Adjuncts:

Discount Factor Tables, Adjunct to Practice E 917³

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 1121⁴

3. Terminology

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

¹ This practice is under the jurisdiction of ASTM Committee E-6 on Performance of Buildings and is the direct responsibility of Subcommittee E06.81 on Building Economics.

Current edition approved Jan. 15, 1993. Published March 1993. Originally published as E 964 – 83. Last previous edition E 964 – 89.

² *Annual Book of ASTM Standards*, Vol 04.11.

³ Available from ASTM Headquarters. Order PCN 12-509179-10.

⁴ 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. Summary of Practice

4.1 This practice identifies related ASTM standards and adjuncts. It outlines the recommended steps for carrying out an analysis using the BCR or SIR method, explains each step, and gives examples. This practice discusses the importance of specifying objectives, alternatives, and constraints at the outset of an evaluation. It identifies data and assumptions needed for calculating BCRs and SIRs, and shows how to calculate the ratios. This practice emphasizes the importance of correctly interpreting the meaning of the ratios in different applications, and of taking into account uncertainty, unquantified effects, and funding constraints. It identifies requirements for documentation and recommends appropriate contents for a BCR or SIR report. This practice also explains and illustrates the application of the BCR and SIR methods to decide whether to accept or reject a project, how much to invest in a project, and how to allocate limited investment funds among competing uses.

5. Significance and Use

5.1 The BCR and SIR provide measures of economic performance in a single number that indicates whether a proposed building or building system is preferred over a mutually exclusive alternative that serves as the base for computing the ratio. It may be contrasted with the life-cycle cost (LCC) method that requires two LCC measures to evaluate the economic performance of a building or building system—one for each alternative.

5.2 The ratio indicates discounted dollar benefits (or savings) per dollar of discounted costs.

5.3 The BCR or SIR can be used to determine if a given building or building system is economic relative to the alternative of not having it.

5.4 The BCR or SIR computed on increments of benefits (or savings) and costs can be used to determine if one design or size of a building or system is more economic than another.

5.5 The BCR or SIR can be used as an aid to select the economically efficient set of projects among many competing for limited funding. The efficient set of projects will maximize aggregate net benefits or net savings obtainable for the budget.

6. Procedure

6.1 The recommended steps for carrying out an economic evaluation using the BCR or SIR method are summarized as follows:

6.1.1 Identify objectives, constraints, and alternatives (see Section 7),

6.1.2 Compile data and establish assumptions for the evaluation (see Section 8),

6.1.3 Compute BCR or SIR (see Section 9),

6.1.4 Analyze the BCR or SIR results and make a decision, taking into account uncertainty, unquantified effects, and funding or cash-flow constraints (see Section 10), and

6.1.5 Document the evaluation and prepare a report if needed (see Section 11).

7. Objectives, Constraints, and Alternatives

7.1 First, the decisionmaker's objectives should be clearly specified. This is crucial to defining the problem and determining the suitability of the BCR or SIR method. Second,

constraints that limit potential alternatives for accomplishing the objectives should be identified. Third, alternatives that are technically and otherwise feasible in light of the constraints should be identified.

7.2 The example in this section illustrates the objective, constraints, and alternatives for a building investment that could be evaluated using the BCR method. The decisionmaker's objective is to maximize net benefits (profits) from investment in new stores in a national chain. The problem is to choose locations for the stores. There are two constraints: (1) the chain already has a sufficient number of stores in the northeast, and (2) there is only enough investment capital to open five stores. Twelve alternative locations (excluding locations in the northeast) are identified as potentially profitable. The BCR can help the decisionmaker identify which five of the twelve potential locations will maximize aggregate net benefits (profits) from the available budget. The approach is to compute a BCR for each location and rank the locations in descending order of their BCRs. If the budget cannot be fully allocated by selecting locations in descending order of their BCRs, the computation of aggregate net benefits is recommended to confirm that aggregate net benefits are maximized by the selected locations.

7.3 The example in this section describes the objective, constraints, and alternatives for a building investment that could be evaluated using the SIR method. The building is a jail. The objective is to reduce the cost of maintaining a target level of security (as might be measured by number of escapees per year). Constraints are that techniques to increase security must be unobtrusive to the surrounding neighborhood and must have low maintenance. The superintendent of prisons is evaluating with the SIR method a new perimeter detection device that costs \$1 million to install, and reduces labor costs for guards by 30%. If the SIR is greater than 1.0, the device is deemed cost effective.

8. Data and Assumptions

8.1 Guidelines for compiling data and making assumptions are treated in detail in Practice E 917, and therefore they are discussed only briefly here.

8.2 To calculate BCR or SIR, estimates typically are needed for revenue or other benefits; acquisition costs, including costs of planning, design, engineering, construction, purchase, installation, land, and site preparation; utility costs, including costs of energy, water, and sewage; nonenergy operating and maintenance costs; repair and replacement costs; resale or retention values; disposal costs; insurance costs; and, if applicable, functional use costs. The microcomputer program database and adjunct user's guide are helpful in estimating maintenance, repair, and replacement costs.

8.3 Information is also needed regarding the study period, discount rate, tax rates and applicable tax rules, and, if an integral part of the investment package, the terms of financing. (These topics are treated in Section 8 of Practice E 917.)

8.4 The outcome of an analysis will vary, depending on the data estimates and assumptions. Thus, it is important to select carefully the assumed values for critical parameters to arrive at a realistic solution.

8.5 If the outcome appears particularly sensitive to the value

assigned to a given parameter, and the estimate is of poor or unknown quality, the analyst may wish to improve the quality of the data. (Sensitivity analysis, a useful technique for identifying critical parameters, is treated in Section 10.3 of Practice E 917.)

8.6 According to personal preference or organizational policy, the analyst normally adopts a simplified model of cash-flow timing to describe the occurrence of costs and benefits within each year; elects whether to express discounted amounts in present-value dollars or in annual-value dollars; and decides whether to work in constant dollars using a real discount rate or in current dollars using a nominal discount rate. (These topics are treated in Section 8 of Practice E 917.)

8.7 The level of effort that goes into the evaluation may range from an inexpensive, back-of-the-envelope calculation intended to provide a ball-park estimate, to an expensive, detailed, thoroughly documented analysis intended to withstand scrutiny and to provide as much accuracy as possible. Different levels of effort are appropriate for different circumstances. (Factors influencing the level of effort are discussed in the paragraph on comprehensiveness in Section 8 of Practice E 917.)

9. Calculation of BCR and SIR⁵

9.1 In concept, the BCR and SIR are simple: benefits (or savings) divided by costs, where all dollar amounts are discounted to present or annual values.

9.2 In practice, it is important to formulate the ratio so as to satisfy the investor's objective. This requires attention to the placement of costs in the numerator and denominator. To maximize net benefits from a designated expenditure, it is necessary to place in the denominator only that portion of costs on which the investor wishes to maximize returns. For example, to maximize the return on investor equity, place only that part of the investment budget representing investor's equity funds in the denominator of the ratio; deduct other costs from benefits or savings in the numerator. On the other hand, to maximize the return on the total of equity *and* borrowed investment funds, place their sum in the denominator of the ratio.

9.3 Formulation is important because changing the placement of cost and benefit items can induce changes in the ratio. Changing the placement of a cost item from the denominator (where it increases costs) to the numerator (where it decreases benefits or savings) will *not* cause a project that appears economic by one formulation of the ratio to appear uneconomic by a different formulation. But changes in the numerical value of the ratio can affect relative rankings of competing, independent projects, and thereby influence investment decisions.

9.4 Biasing effects, detrimental to economic efficiency, can result from certain formulations of the BCR and SIR ratios. For example, when allocating an investment budget among com-

peting projects that differ significantly in their maintenance costs, placing maintenance costs in the denominator with investment costs tends to bias selection away from projects with relatively high maintenance costs, even when they offer higher net benefits (profits) than competing projects. Similar biasing effects can occur in the placement of other noninvestment costs such as energy or labor costs. This outcome reflects the fact that adding a given amount to the denominator of a ratio reduces the quotient more than does subtracting an identical amount from the numerator. Placing all noninvestment costs in the numerator will eliminate this bias when the objective is to maximize the return on the investment budget.

9.5 Eq 1 and 2 provide formulations of the BCR and SIR that avoid biasing effects, and allow the analyst flexibility in choosing the part of the investment budget on which to maximize the return. Eq 1 is used when benefits predominate, and Eq 2 when a project's primary advantage is lower costs.

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

where:

BCR = benefit-to-cost ratio,

B_t = benefits in period t ; that is, advantages in revenue or performance, measured in dollars, of the building or system as compared with a mutually exclusive alternative (See Note 1),

\bar{C}_t = costs in period t , excluding investment costs that are to be placed in the denominator for the building or system, less counterpart costs in period t for a mutually exclusive alternative,

\bar{I}_t = those investment costs in period t on which the investor wishes to maximize the return, less similar investment costs in period t for a mutually exclusive alternative, and

i = the discount rate.

NOTE 1—Mutually exclusive alternatives are those for which accepting one automatically means not accepting the others. For a given project one mutually exclusive alternative may be not to undertake the project. If so, it is against this alternative that a potential investment must be compared to determine its cost-effectiveness. Alternative designs and sizes of a project for a given application are also mutually exclusive.

$$SIR = \frac{\sum_{t=0}^N S_t/(1+i)^t}{\sum_{t=0}^N \bar{I}_t/(1+i)^t} \quad (2)$$

where:

SIR = savings-to-investment ratio, and

S_t = cost savings in period t , adjusted to include any benefits in period t , for the building or building system to be evaluated.

That is:

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

where:

⁵ A computer program that produces BCR and SIR measures consistent with this practice is Petersen, S. R., "The NIST Building Life-Cycle Cost (BLCC) Computer Program" and documentation—*The NIST Building Life-Cycle Cost (BLCC) Program: User's Guide and Reference Manual*, NISTIR 5185-3, National Institute of Standards and Technology, 1995.

$$\left| \sum_{t=0}^N \bar{C}_t \right| \gg \sum_{t=0}^N B_t \text{ and } \sum_{t=0}^N \bar{C}_t < 0.$$

NOTE 2—The BCR is normally used instead of the SIR unless cost reductions are *much* greater than revenue and performance advantages; hence the use of the symbol \gg in the definition of S_r .

9.6 When financing is included in the analysis, I is typically set equal to investment costs paid up-front by the investor, that is, the downpayment paid out of equity funds. When financing is not included in the analysis, I is typically set equal to the total of investment costs.

9.7 Equation 3 is an alternative formulation of the BCR that gives the same mathematical results as Eq 1:

$$\text{BCR} = \frac{\text{NB} + \left(\sum_{t=0}^N \bar{I}_t / (1+i)^t \right)}{\sum_{t=0}^N \bar{I}_t / (1+i)^t} \quad (3)$$

where:

NB = net benefits, and

$$\text{NB} = \sum_{t=0}^N (B_t - \bar{C}_t - \bar{I}_t) / (1+i)^t.$$

NOTE 3—Investors may prefer in some cases a formulation of the ratio that has a bias, as the term is used here, because they may wish to maximize the return on a particular type of fund. For example, current account expenditures might be the constraining resource, and they might wish to maximize the return on current account expenditures.

9.8 For ease of computation, instead of discounting the amount in each year and summing, as called for in Eq 1-3, the cash flows can be grouped into categories with the same pattern of occurrence and discounted using discount factors. (How to discount different patterns of cash flows is explained in the Section 9 of Practice E 917.)

9.9 If income tax effects are a significant factor, they should be included in the analysis. (Income tax adjustments are treated in Section 9 of Practice E 917 and are illustrated in Appendix X1 of this practice.)

10. Analysis of BCR or SIR Results and the Decision

10.1 Care must be taken to interpret correctly the results of the BCR or SIR.

10.1.1 When a given, discretionary investment is compared against the alternative of doing nothing, a ratio greater than 1.0 indicates that the investment's benefits or savings exceed its costs. This supports accepting the investment on economic grounds, as opposed to doing nothing. For example, an SIR greater than 1.0 on an investment in a central vacuuming system for an office building indicates that the system is estimated to be cost effective. The higher the ratio, the more economically attractive the investment. (Accepting or rejecting individual investments is treated further in 12.2.)

10.1.2 When comparing alternative designs or sizes of a given building or building system, the alternative with the highest BCR or SIR is usually *not* the most economic choice. For design and sizing decisions it is important to compute incremental BCRs and SIRs by dividing the additional benefits or savings gained from an expansion in investment by the additional investment cost. It pays to expand an investment as

long as incremental benefits or savings from the expansion exceed incremental costs. Net benefits (or net savings) reach their maximum when the incremental BCR or SIR equals 1.0. For example, if increasing the level of thermal insulation in a house from R-11 (resistance level = 11) to R-19 gives an incremental SIR of 5.0, the increment is cost effective. If further increasing the level of insulation from R-19 to R-30 gives an incremental SIR of 3.0, that increment is also cost effective. And, if increasing the insulation from R-30 to R-38 gives an incremental SIR greater than 1.0, it pays to expand the level to R-38. (Project design and sizing is treated further in 12.4.)

10.1.3 Using BCRs or SIRs to assign priority among independent, competing projects *suggests* the optimum selection, but is not always a reliable approach. If project costs are "lumpy" such that the budget cannot be used up exactly by adhering strictly to the BCR or SIR ranking, the optimum selection may differ from that indicated by the ratios. (Allocating a budget is treated further in 12.3.)

10.2 The final investment decision should take into account not only the numerical values of the BCRs or SIRs, but also uncertainty of investment alternatives relative to the risk attitudes of the investor, the availability of funding and other cash-flow constraints, any unquantified effects attributable to the alternatives, and the possibility of noneconomic objectives. (These topics are discussed in Section 10 of Practice E 917.)

11. BCR or SIR Report

11.1 A report should document the BCR or SIR analysis. Key data and assumptions should be identified for each of the alternatives considered. Significant effects that remain unquantified should be described in the report. And it should explain the basis for arriving at a decision. (This topic is discussed in more detail in Section 11 of Practice E 917.)

12. Applications

12.1 The BCR and SIR methods can be used to indicate whether a given investment is economically attractive, to choose among nonmutually exclusive projects competing for a limited budget, and to determine which engineering alternative (that is, which project design or size) is most economically efficient. This practice gives five illustrations of applications of the BCR and SIR methods. One is a detailed example of a real estate investment problem. It appears in Appendix X1. The other four are brief illustrations presented in Tables 1-5.

12.2 *Accepting or Rejecting Individual Investments:*

12.2.1 If an investment's BCR or SIR is greater than 1.0, its discounted benefits or savings exceed its discounted costs, and it is economically attractive. On the other hand, if the ratio is less than 1.0, discounted benefits or savings are less than discounted costs, and it is not economically attractive.

12.2.2 An illustration of the application of the BCR method to decide whether to accept an investment in real estate is given in Appendix X1. The example shows the evaluation of an investment in an apartment building. It is an after-tax evaluation, and shows year-by-year cash flows. The BCR of 5.36 means that the real estate investment is estimated to return \$5.36 for every dollar invested, over and above the minimum required rate of return imposed by the discount rate.