Designation: E964 – 15 (Reapproved 2020)ε1

Standard Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for Buildings and Building Systems[1]

This standard is issued under the fixed designation E964; 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.

ε[1] NOTE—Adjunct title and stock number in 2.2 were updated editorially in April 2020.

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, net savings, life-cycle cost, internal rate-of-return, adjusted internal rate-of-return, and payback (see Practices E917, E1057, E1074, and E1121). Guide E1185 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 covers 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.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E631 Terminology of Building Constructions

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

Current edition approved April 1, 2020. Published May 2020. Originally approved in 1983. Last previous edition approved in 2015 as E964-15. DOI: 10.1520/E0964-15R20E01.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E833 Terminology of Building Economics
E917 Practice for Measuring Life-Cycle Costs of Buildings and Building Systems
E1057 Practice for Measuring Internal Rate of Return and Adjusted Internal Rate of Return for Investments in Buildings and Building Systems
E1074 Practice for Measuring Net Benefits and Net Savings for Investments in Buildings and Building Systems
E1121 Practice for Measuring Payback for Investments in Buildings and Building Systems
E1185 Guide for Selecting Economic Methods for Evaluating Investments in Buildings and Building Systems
E1369 Guide for Selecting Techniques for Treating Uncertainty and Risk in the Economic Evaluation of Buildings and Building Systems
E1765 Practice for Applying Analytical Hierarchy Process (AHP) to Multiattribute Decision Analysis of Investments Related to Projects, Products, and Processes
E1946 Practice for Measuring Cost Risk of Buildings and Building Systems and Other Constructed Projects
E2204 Guide for Summarizing the Economic Impacts of Building-Related Projects

2.2 *ASTM Adjunct:*[3]

Discount Factor Tables - Adjunct to E917 Practice for Measuring Life-Cycle Costs of Buildings and Building Systems - Includes Excel and PDF Files

3. Terminology

3.1 *Definitions*—For definitions of general terms related to building construction used in this practice, refer to Terminology E631; and for general terms related to building economics, refer to Terminology E833.

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 decision-maker'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 decision-maker'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 decision-maker 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

[3] Available from ASTM International Headquarters. Order Adjunct No. ADJE091717-EA. Original adjunct produced in 1984. Adjunct last revised in 2003.

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 dollars 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 E917, 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.

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 E917.)

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 10.3 of Practice E917.)

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 E917.)

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 E917.)

9. Calculation of BCR and SIR[4]

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 competing 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.

[4] The NIST Building Life-Cycle Cost (BLCC) Computer Program helps users calculate measures of worth for buildings and building components that are consistent with ASTM standards. The program is downloadable from: http://www.eere.energy.gov/femp/information/download_blcc.html.