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An American National Standard

Standard Practice for Measuring Net Benefits for Investments in Buildings and Building Systems[1]

This standard is issued under the fixed designation E 1074; 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—Footnote 5 of this standard was editorially corrected in September 1998.

INTRODUCTION

The net benefits (NB) method is part of a family of economic evaluation methods that provide measures of economic performance of an investment over some period of time. Included in this family of evaluation methods are life-cycle cost analysis, benefit-to-cost and savings-to-investment ratios, internal rates of return, and payback analysis.

The NB method, sometimes called the net present value method, calculates the difference between discounted benefits (or savings) and discounted costs as a measure of the cost effectiveness of a project. The NB method is used to decide if a project is cost effective (net benefits greater than zero) or which size or design competing for a given purpose is most cost effective (the one with the greatest net benefits).

1. Scope

1.1 This practice provides a recommended procedure for calculating and interpreting the NB method in the evaluation of building designs and systems.

2. Referenced Documents

2.1 *ASTM Standards:*

E 833 Terminology of Building Economics[2]

E 917 Practice for Measuring Life-Cycle Costs of Buildings and Building Systems[2]

E 964 Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for Buildings and Building Systems[2]

E 1057 Practice for Measuring Internal Rate of Return and Adjusted Internal Rate of Return for Investments in Buildings and Building Systems[2]

E 1121 Practice for Measuring Payback for Investments in Buildings and Building Systems[2]

E 1185 Guide for Selecting Economic Methods for Evaluating Investments in Buildings and Building Systems[2]

2.2 *ASTM Adjuncts:*

Discount Factor Tables,

Adjunct to Practice E 917[3]

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[4]

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* 2, *Referenced Documents*—Lists ASTM standards referenced in this practice.

4.1.2 *Section* 3, *Definitions*—Addresses definitions of terms used in this practice.

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

4.1.4 *Section* 5, *Significance and Use*—Explains the application of the practice and how and when it should be used.

4.1.5 *Section* 6, *Procedures*—Summarizes the steps in making NB analysis.

4.1.6 *Section* 7, *Compute NB*—Describes calculation procedures for NB.

4.1.7 *Section* 8, *Applications*—Explains circumstances under which the NB method is appropriate.

[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.

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[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.

TABLE 1 Calculation of Net Benefits

Year, t	Benefits, B_t, dollars	Costs, $\bar{C}_t$, dollars	Net Cash Flow[A] $B_t - \bar{C}_t$, dollars	SPV Factor[B] for i = 15 %	PVNB, dollars
0	0	10 000	−10 000	1.000	−10 000
1	4 000	3 000	+1 000	0.8696	+870
2	11 500	4 500	+7 000	0.7561	+5 293
3	10 000	4 000	+6 000	0.6575	+3 945
4	8 000	5 000	+3 000	0.5718	+1 715
Total	33 500	26 500	+7 000		+1 823

[A] To find the PVNB of the net cash flow for each discounting period, the single present value (SPV) discount factor is multiplied times the net cash flow. For an explanation of discounting factors and how to use them, see *Discount Factor Tables,* adjunct to Practice E 917.

4.1.8 *Section* 9, *Report*—Identifies information that should be included in a report of a NB analysis.

5. Significance and Use

5.1 The NB method provides a measure of the economic performance of an investment, taking into account all relevant monetary values associated with that investment over the investor's study period. The NB measure can be expressed in either present value or equivalent annual value terms, taking into account the time value of money.

5.2 The NB method is used to decide if a given project is cost effective and which size or design for a given purpose is most cost effective when no budget constraint exists.

5.3 The net benefits method can also be used to determine the most cost effective combination of projects for a limited budget; that is, the combination of projects having the greatest aggregate net benefits and fitting within the budget constraint.

6. Procedures

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

6.1.1 Make sure that the NB method is the appropriate economic measure (see Guide E 1185),

6.1.2 Identify objectives, alternatives, and constraints,

6.1.3 Establish assumptions,

6.1.4 Compile data (see the adjunct entitled "Computer Program and User's Guide to Building Maintenance, Repair, and Replacement Database for Life-Cycle Cost Analysis"),

6.1.5 Convert cash flows to a common time basis (discounting),

6.1.6 Compute NB[5] and compare alternatives, and

6.1.7 Make final decision, based on NB results as well as consideration of risk and uncertainty, unquantifiable effects, and funding constraints (if any).

6.2 Since the steps mentioned in 6.1.1-6.1.4 and in 6.1.7 are treated in detail in Practice E 917 and briefly in Practices E 964 and E 1121, they are not discussed in this practice. In calculating NB, these four steps should be followed exactly as described in Practice E 917. The remainder of this practice focuses on the computation and application of the NB measure.

7. NB Computation

7.1 Computation of net benefits for any given project requires the estimation, in dollar terms, of differences between benefits, and differences between costs, for that project relative to a mutually exclusive alternative. The mutually exclusive alternative may be a similar design/system of a different scale, a dissimilar design/system for the same purpose, or the *do nothing* case. Benefits can include (but are not limited to) revenue, productivity, functionality, durability, resale value, and tax advantages. Costs can include (but are not limited to) initial investment, operation and maintenance (including energy consumption), repair and replacements, and tax liabilities.

7.2 Eq 1 is used to compute the present value of net benefits (PVNB) for the proposed project relative to its mutually exclusive alternative.

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

where:

B_t = dollar value of benefits in period t for the building or system being evaluated less the counterpart benefits in period t for the mutually exclusive alternative against which it is being compared,

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

N = number of discounting time periods in the study period, and

i = the discount rate per time period.

7.3 Eq 2 can be used to convert the present value of net benefits to annual value terms, where N is the number of years in the study period.

$$\mathrm{AVNB} = \mathrm{PVNB} \cdot [(i(1 + i)^N)/((1 + i)^N - 1) \quad (2)$$

where AVNB = annual value of net benefits.

7.4 For a given problem and data set, solutions in either present value or annual value terms will be time equivalent values (although different in actual dollar values) and will result in the same investment or design decisions, provided annual values are calculated using Eq 2.

7.5 A simple application of Eq 1 is presented in Table 1 for an initial investment of $10 000 that yields an uneven yearly cash flow over four years. (Implicitly, the mutually exclusive alternative is the *do nothing* case.) Assuming a discount rate of 15 %, the discounted cash flows yield a PVNB of $1 823. (Note that the sum of net cash flows, $7 000, is a much larger

[5] A computer program that produces NB 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.

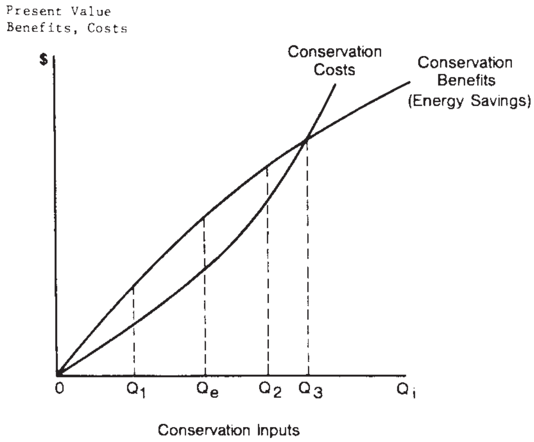

FIG. 1 Finding the Level of Energy Conservation That Maximizes the PVNB

value, since it fails to account for the time value of money.) The larger the PVNB for a given project, the more economically attractive it will be, other things being equal.

7.6 To find the AVNB that is time equivalent to $1 823, Eq 2 can be used. The equivalent AVNB is $639.

8. Applications

8.1 The NB measure indicates that a given project is cost effective if the PVNB is greater than zero. If the PVNB is less than zero, then the project is not cost effective.

8.2 How large an investment to make (that is, what is the most economically efficient scale) is generally answered with NB analysis. The size or scale of investment is increased until the PVNB is maximized. Typical size or scale examples from the building industry include (1) how large a building to construct, (2) how large a dam to construct, (3) how much insulation to put in a house, and (4) how many square feet of collector area to install in a solar energy system.

8.3 Fig. 1 illustrates graphically how the NB method is used to choose the economically efficient level of energy conservation in a building (that is, where the PVNB is maximized). Conservation costs, in present value terms, are shown to increase at an increasing rate as the physical quantity of inputs to conserve energy (Q_i) is increased (for example, increased insulation). Conservation benefits (in present value terms), as measured by energy savings, also increase with additional inputs to energy conservation, but at a decreasing rate. The difference between these dollar conservation benefits and costs at any given level of conservation inputs is the PVNB. The level of energy conservation where the PVNB is maximized is Q_e. Any smaller (Q_1) or larger investments (Q_2 or Q_3) than Q_e would be economically inefficient, because the potential PVNB (profit) is greatest at Q_e(Note 1). Therefore, when using PVNB as a guide, the economically efficient level of insulation for a building is found by increasing applications of insulation until the PVNB is maximized.

NOTE 1—The efficient size could be smaller than Q_e if the investment budget were limited and if other projects were available with incremental benefit-to-cost ratios greater than one.

8.4 Fig. 1 also illustrates the application described in 8.1. That is, any level of conservation inputs portrayed in Fig. 1 within the bounds of zero and Q_3 would be a cost-effective investment.

8.5 The NB method is also used to compare projects or designs competing for the same purpose to see which is most economically efficient. Typical examples from the building industry include: (*1*) how to select between single, double, or triple glazing; (*2*) how to choose between a solar energy system and a conventional energy system; and (*3*) how to choose between a large dam and a small dam with levees to provide flood control. The most economically efficient project in each case would be the one with the greatest PVNB (Note 2). Applying Eq 1, for example, to the selection of a flood control project, if PVNB is greater for the small dam and levees than for the large dam, then the small dam and levees are the economically preferred system.

NOTE 2—In these applications of NB analysis, it is assumed that the initial cost of the alternatives considered does not exceed the available budget.

8.5.1 In using PVNB to compare mutually exclusive projects (that is, a set of projects from which one alternative can be selected), a common study period is required for a valid economic comparison.

8.5.1.1 In comparing projects competing for the same purpose, the analyst must sometimes normalize the PVNB with respect to time in order to have a valid economic comparison. The PVNB of projects with identical expected lives can be compared directly. If the expected lives are different, however, adjustments are required. A common adjustment is to convert each project's life to the least common multiple of the lives of all projects under consideration. By making assumptions about reinvestment costs and earnings, a time-normalized PVNB can then be calculated for each project for comparison over the common study period.

8.5.1.2 A second approach is to select the relevant time horizon of the investor as the length of the study period. Then use replacements and residual values to evaluate each alternative within the common study period.

8.5.1.3 A third approach for comparing projects with unequal lives is to convert the PVNB calculated on the basis of each project's life to an annual value of net benefits (AVNB) using Eq 2. The AVNB will yield a valid economic comparison if the costs and benefits of each project are replicated exactly with each replacement.

8.6 Aggregate PVNB can be used to determine the most cost effective allocation of a limited budget among nonmutually exclusive projects. In general, the combination of projects with the greatest aggregate PVNB fitting within the budget constraint is the most cost effective allocation. In order to aggregate the net benefits of nonmutually exclusive projects, they must all be computed over the same study period.

9. Report

9.1 A report of a NB analysis should include the following information:

9.1.1 The objective and the alternatives considered.

9.1.2 Key assumptions and data including:

9.1.2.1 Discount rate,
9.1.2.2 Study period,
9.1.2.3 Cost data,
9.1.2.4 Benefits (savings) data,
9.1.2.5 Grants, tax deductions, and
9.1.2.6 Financing terms.

9.1.3 The tax status of the investor together with the method of treating inflation.

9.1.4 Any significant effects that are not quantified in the NB measure.

10. Keywords

10.1 benefit-cost analysis; building economics; economic evaluation methods; engineering economics; life-cycle cost analysis; net benefits; net savings