Designation: E917 – 17ε1

Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems[1]

This standard is issued under the fixed designation E917; 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 information in 2.2 was updated editorially in May 2020.

INTRODUCTION

Several methods of economic evaluation are available to measure the economic performance of a building or building system over a specified time period. These methods include, but are not limited to, life-cycle cost (LCC) analysis, the benefit-to-cost ratio, internal rate of return, net benefits, payback, multi-attribute decision analysis, risk analysis, and related measures (see Practices E964, E1057, E1074, E1121, E1765, and E1946). These methods differ in their measure and, to some extent, in their applicability to particular types of problems. Guide E1185 directs you to the appropriate method for a particular economic problem. One of these methods, life-cycle cost (LCC) analysis, is the subject of this practice. The LCC method sums, in either present-value or annual-value terms, all relevant costs associated with a building or building system over a specified time period. Alternative (mutually exclusive) designs or systems for a given functional requirement can be compared on the basis of their LCCs to determine which is the least-cost means of satisfying that requirement over a specified study period.

1. Scope

1.1 This practice establishes a procedure for evaluating the life-cycle cost (LCC) of a building or building system and comparing the LCCs of alternative building designs or systems that satisfy the same functional requirements.

1.2 The LCC method measures, in present-value or annual-value terms, the sum of all relevant costs associated with owning and operating a building or building system over a specified time period.

1.3 The basic premise of the LCC method is that to an investor or decision maker all costs arising from an investment decision are potentially important to that decision, including future as well as present costs. Applied to buildings or building systems, the LCC encompasses all relevant costs over a designated study period, including the costs of designing, purchasing/leasing, constructing/installing, operating, maintaining, repairing, replacing, and disposing of a particular building design or system.

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 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

E833 Terminology of Building Economics

E964 Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for 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

[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 Sept. 1, 2017. Published November 2017. Originally approved in 1983. Last previous edition approved in 2015 as E917 – 15. DOI: 10.1520/E0917-17E01.

[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.

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 Standard 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 the 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 outlines the recommended procedures for computing the LCCs associated with a building or building system over a specified time period. It identifies and gives examples of objectives, alternatives, and constraints for an LCC analysis; identifies project data and general assumptions needed for the analysis; and presents alternative approaches for computing LCCs. This practice requires that the LCCs of alternative building designs or systems be compared over a common time period to determine which design or system has the lowest LCC. This practice also states that uncertainty, unquantifiable effects, and funding constraints shall be considered in the final analysis. It identifies the recommended contents of an LCC report, describes proper applications of the LCC method, provides examples of its use, and identifies limitations of the method. A comprehensive example of the LCC method applied to a building economics problem is provided in Appendix X1. A comprehensive example illustrating the treatment of uncertainty within the LCC method is provided in Appendix X2. Appendix X3 provides a detailed example analyzing the life-cycle cost implications resulting from energy efficiency improvements in a high school building. Appendix X4 provides a description of the Adjunct.

5. Significance and Use

5.1 LCC analysis is an economic method for evaluating a project or project alternatives over a designated study period. The method entails computing the LCC for alternative building designs or system specifications having the same purpose and then comparing them to determine which has the lowest LCC over the study period.

5.2 The LCC method is particularly suitable for determining whether the higher initial cost of a building or building system is economically justified by reductions in future costs (for example, operating, maintenance, repair, or replacement costs) when compared with an alternative that has a lower initial cost but higher future costs. If a building design or system specification has both a lower initial cost and lower future costs relative to an alternative, an LCC analysis is not needed to show that the former is the economically preferable choice.

5.3 If an investment project is not essential to the building operation (for example, replacement of existing single-pane windows with new double-pane windows), the project must be compared against the "do nothing" alternative (that is, keeping the single pane windows) in order to determine if it is cost effective. Typically the "do nothing" alternative entails no initial investment cost but has higher future costs than the proposed project.

6. Procedure

6.1 Follow these steps in calculating the LCC for a building or building system:

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

6.1.2 Establish basic assumptions for the analysis (see 8.1).

6.1.3 Compile cost data (see 8.2).

6.1.4 Compute the LCC for each alternative (see Section 9).

6.1.5 Compare LCCs of each alternative to determine the one with the minimum LCC (see 10.1).

6.1.6 Make final decision, based on LCC results as well as consideration of risk and uncertainty, unquantifiable effects, and funding constraints (if any) (see 10.2, 10.3, 10.4, and 10.5).

7. Objectives, Alternatives, and Constraints

7.1 Specify the design or system objective that is to be accomplished, identify alternative designs or systems that accomplish that objective, and identify any constraints that limit the available options to be considered.

7.2 An example is the selection of a space heating system for a new house. The system must satisfy the thermal comfort requirements of the occupants throughout the heating season. Available alternatives (for example, various gas furnaces, oil furnaces, heat pumps, and electric baseboard heaters) may have different types of fuel usage with different unit costs, different fuel conversion efficiencies, different initial costs and expected maintenance and repair costs, and different lives. System selection will be constrained to those fuel types available at the building site.

8. Data and Assumptions

8.1 *Basic Assumptions*—Establish the uniform assumptions to be made in the economic analysis of all alternatives. These assumptions usually include, but are not limited to, the consistent use of the present-value or annual-value calculation method, the base time and study period, the general inflation rate, the discount rate, the marginal income tax rate (where

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

relevant), the comprehensiveness of the analysis, and the operational profile of the building or system to be evaluated.

8.1.1 *Present-Value Versus Annual-Value Calculations*—The LCCs of project alternatives must be calculated uniformly in present-value or annual-value terms. In the former, all costs are discounted to the base time; in the latter, all costs are converted to a uniform annual amount equivalent to the present value when discounted to the base time.

8.1.2 *Study Period*—The study period appropriate to the LCC analysis may or may not reflect the life of the building or system to be evaluated. The same study period must be used for each alternative when present-value calculations are used. An annual-value LCC may, under certain restrictive assumptions, be used to compare alternatives with different study periods (see 9.2.3). The following guidelines may be useful for selecting a study period for an LCC analysis:

8.1.2.1 When analyzing a project from an individual investor's standpoint, the study period should reflect the investor's time horizon. For a homeowner, the study period for a house-related investment might be based on the length of time the homeowner expects to reside in the house. For a commercial property owner, the study period might be based on the anticipated holding period of the building. For an owner/occupant of a commercial building, the study period might correspond to the life of the building or building system being evaluated. For a speculative investor, the study period might be based on a relatively short holding period. For investments by government agencies and large institutions, specific internal policies often direct the choice of study period.

8.1.2.2 When LCC analyses of alternative building systems or design practices are performed for general information rather than for a specific application (for example, government or industry research to determine the cost effectiveness of thermal insulation or high-efficiency heating and cooling equipment in typical installations), the study period will often coincide with the service life of the material or system (but be limited to the typical life of the type of building where it is to be installed). When the service life is very long, a more conservative choice for the study period might be used if the uncertainty associated with the long-term forecasting of costs substantially reduces the credibility of the results.

8.1.2.3 Regardless of the type of investor or purpose of the analysis, use the same study period for all categories of costs when calculating the present value of any cost associated with a project. Furthermore, when comparing alternative designs or systems on the basis of their present-value LCCs, use the same study period for each investment alternative.

8.1.2.4 When the study period selected is significantly shorter than the service life of the building or system evaluated, it is important that a realistic assessment of the project's resale (or residual) value at the end of the study period be included in the LCC analysis. Even if the building will not be sold at that time, the resale value will likely have a significant impact on the LCC.

8.1.3 *Inflation*—General price inflation is the reduction in the purchasing power of the dollar from year to year, as measured, for example, by the percent increase in the gross national product (GNP) deflator over a given year. LCC analyses can be calculated in constant-dollar terms (net of general inflation) or in current-dollar terms (including general inflation). If the latter is used, a consistent projection of general price inflation must be used throughout the LCC analysis, including adjustment of the discount rate to incorporate the general inflation rate.

8.1.3.1 When income tax effects are not included in the LCC analysis, as in the case of LCC evaluations of nonprofit buildings and owner-occupied houses (without financing), it is usually easier to express all costs in constant dollars. Price changes for individual cost categories that are higher or lower than the rate of general inflation can be included by using differential rates of price change for those categories.

8.1.3.2 When income tax effects are included in the LCC analysis, it is usually easier to express all costs in current dollars because income taxes are tied to current-dollar cash flows rather than constant-dollar cash flows.

8.1.4 *Discount Rate*—The discount rate selected should reflect the investor's time value of money. That is, the discount rate should reflect the rate of interest that makes the investor indifferent between paying or receiving a dollar now or at some future point in time. The discount rate is used to convert costs occurring at different times to equivalent costs at a common point in time.

8.1.4.1 Select a discount rate equal to the rate of return on the next best available use of funds. Where the discount rate is legislated or mandated for a given institution, that rate takes precedence.

8.1.4.2 A discount rate that includes general price inflation over the study period is referred to as the "nominal" discount rate in this practice. A discount rate expressed in terms net of general price inflation is referred to as the "real" discount rate.

8.1.4.3 A nominal discount rate, i, and its corresponding real discount rate, r, are related as follows:

$$r = \frac{1+i}{1+I} - 1 \quad \text{or} \quad i = (1+r)(1+I) - 1 \tag{1}$$

where:

I = the rate of general price inflation.

8.1.4.4 Use a real discount rate if estimates of future costs are expressed in constant dollars, that is, if they do not include general inflation.

8.1.4.5 Use a nominal discount rate if estimates of future costs are expressed in current dollars, that is, if they include general inflation.

8.1.4.6 When alternative building or system designs are compared using the LCC method, use the same discount rate in each LCC computation.

8.1.5 *Comprehensiveness*—Different levels of effort can be applied in undertaking an LCC analysis. The appropriate level of comprehensiveness depends upon the degree of complexity of the problem, the intended purpose of the evaluation, the level of monetary and nonmonetary impacts contingent upon the investment decision, the cost of the different levels of comprehensiveness, and the resources available to the investor or decision maker.

8.1.5.1 Some anticipated effects are more difficult to quantify in monetary terms than others. Include effects that are