Designation: A930 – 09

Standard Practice for
Life-Cycle Cost Analysis of Corrugated Metal Pipe Used for Culverts, Storm Sewers, and Other Buried Conduits[1]

This standard is issued under the fixed designation A930; 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.

1. Scope*

1.1 This practice covers a procedure for using life-cycle cost (LCC) analysis techniques to evaluate alternative drainage system designs using corrugated metal pipe that satisfies the same functional requirements.

1.2 The LCC technique measures the present value of all relevant costs of installing, operating, and maintaining alternative drainage systems, such as engineering, construction, maintenance, rehabilitation, or replacement, over a specified period of time. The practice also accommodates any remaining residual or salvage value.

1.3 Using the results of the LCC analysis, the decision maker can then identify the alternative(s) with the lowest estimated total cost based on the present value of all costs.

1.4 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E917 Practice for Measuring Life-Cycle Costs of Buildings and Building Systems

2.2 *Other Documents:*

TM-5-802-1 Economic Studies for Military Construction Design—Applications (12/86)

Federal Office of Management and Budget Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs and State Documents for Guidelines or Requirements

3. Terminology

3.1 *Definitions:*

3.1.1 *common costs*, *n*—costs common to all alternatives in nature and amounts such as initial planning fees or future annual inspection costs.

3.1.2 *discount rate*, *n*—the investor's time value of money, expressed as a percent, used to convert the costs occurring at different times to equivalent costs at a common point in time.

3.1.3 *drainage project*, *n*—a project having a definable, functional drainage requirement that can be satisfied by two or more design or construction alternatives.

3.1.4 *future costs*, *n*—costs required to keep the system operating that are incurred after the project is placed in service, such as operation, maintenance, rehabilitation, or replacement costs.

3.1.5 *inflation*, *n*—the general trend or rising prices that result in reduction of the purchasing power of the dollar from year to year over time.

3.1.6 *initial cost*, *n*—the total of all costs, such as design costs, material purchase costs, and construction and installation costs, that are specific to each alternative and are incurred to bring each alternative to a point of functional readiness.

3.1.7 *maintenance cost*, *n*—the annual or periodic costs, such as inspection and cleaning, to keep a drainage structure functioning for the project design life but that do not extend the material service life.

3.1.8 *material service life*, *n*— the number of years of service that a particular material, system, or structure will provide before rehabilitation or replacement is necessary.

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[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.

***A Summary of Changes section appears at the end of this standard.**

3.1.9 *project design life*, *n*—the planning horizon for the project, expressed as the number of years of useful life required of the drainage structure.

3.1.10 *rehabilitation cost*, *n*—the total of all costs incurred to extend the material service life of a specific alternative.

3.1.11 *replacement cost*, *n*—the total of all costs incurred to replace a material before the end of the project design life.

3.1.12 *terminal value*, *n*—the remaining value of the drainage structure in place at the end of the project design life.

4. Summary of Practice

4.1 This practice outlines a procedure for conducting an LCC analysis of two or more drainage pipe alternatives using corrugated metal pipe over a specified project design life. It identifies the project data and general assumptions necessary for the analysis and the method of computation.

5. Significance and Use

5.1 LCC analysis is an economic method for evaluating alternatives that are characterized by differing cash flows over the designated project design life. The method entails calculating the LCC of each alternate capable of satisfying the functional requirement of the project and comparing them to determine which has (have) the lowest estimated LCC over the project design life.

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

6. Procedures

6.1 The procedure for performing an LCC analysis for drainage pipe applications is summarized in the following steps:

6.1.1 Identify the project objectives, alternatives, and constraints (6.2).

6.1.2 Establish the basic assumptions (6.3).

6.1.3 Compile data (6.4).

6.1.4 Compute the LCC for each alternative (6.5).

6.1.5 Evaluate the results (6.6).

6.2 *Project Objectives, Alternatives, and Constraints*:

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

6.2.2 An example is the design of a storm water drainage system for a residential development project. The system must satisfy mandated drainage system objectives such as specified rainfall intensities and storm water runoff limits. Available alternatives, such as different pipe materials and varying configurations of catch basins, ponds, or underground detention chambers, may have different initial costs as well as expected future costs. The system design may be constrained by structural and hydraulic limits such as minimum and maximum slopes and depth of burial, limits on surface flows on streets, etc.

6.3 *Basic Assumptions*:

6.3.1 Establish the uniform assumptions to be made in the LCC analysis of all alternatives. These assumptions include the selection of discount rate, treatment of inflation, general inflation rate, project design life, and desired comprehensiveness of the analysis.

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

6.3.2.1 No single correct discount rate exists for all owners. Selection of the discount rate should be guided by the rate of return on alternative investment opportunities of comparable risk (that is, the opportunity costs of capital) or, in the case of some public organizations, on mandated or legislated federal or state requirements.

6.3.2.2 The discount rate may include general price inflation over the study period. This discount rate is referred to as the nominal discount rate in this practice. The discount rate may also be expressed as the real earning power of money over and above general price inflation, referred to as the real discount rate.

6.3.2.3 A nominal discount rate (d_n) and its corresponding real discount rate (d_r) are related as follows:

$$d_r = \frac{1 + d_n}{1 + I} - 1 \text{ or } d_n = (1 + d_r)(1 + I) - 1 \quad (1)$$

where:

I = rate of general price inflation.

6.3.2.4 The same discount rate should be used when evaluating each design alternative. Table 1 contains a procedure to follow when developing the discount rate. This procedure can be applied by those who wish to select their own values as well as those required to follow mandated or legislated requirements.

6.3.3 *Inflation*—This practice is designed to accommodate only a uniform rate of general inflation. The LCC can be calculated in constant dollar terms (not including general inflation) or 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 (6.3.2.2). The percentage change in the GNP deflator and producers price index are two broad indicators of general inflation.

6.3.3.1 If the user desires or is required to treat inflation on an incremental (differential) basis, or uniquely to each individual cost component (for example, energy costs), he or she should consult either TM-5-802-1 or Practice E917, respectively.

6.3.4 *Project Design Life*—The project design life (3.1.9) should be established from mandated public policy, legislated requirements, or selection by the owner based on situation

TABLE 1 Discount Rate Procedure

1.0	*General*—This procedure is intended to guide the user in developing a real discount rate, that is, the long-term rate of return over and above the general inflation rate. This procedure can be used by those required to use rates specified by mandate or legislated requirement, as well as those desiring to select their own values. This procedure does not recommend any specific rates; that selection is up to the user and should be made based on the considerations described in 6.3.2.1.
1.1	Is there a discounted rate that must be used by policy, mandate, or legislated requirements? (check one):
1.1.1	____ Yes. If yes, the discount rate is ____ %
1.1.2	____ No. Proceed to 2.
1.2	____ Does the discount rate in 1.1.1 include inflation? (check one):
1.2.1	____ Yes. If yes, the inflation rate is ____ % (proceed to 2.1.4)
1.2.2	____ No. The rate shown in 1.1.1 is the real discount rate (excludes general inflation) and can be used as d_r in (Eq 3) and (4).
2.	If no discount rate is mandated, two approaches are possible:
2.1	Select a long-term percentage rate of return on invested money, over and above the general inflation rate. This value can be used as d_r in (Eq 3) and (4).
2.2	Select a nominal discount rate (including general inflation): ____ % = (d_n).
2.3	Select a long-term rate of general inflation: ____% = (I).
2.4	Calculate the real discount rate (d_r) for use in (Eq 3) and (Eq 4).

$$d_r = \frac{1 + d_n}{1 + I} - 1$$

requirements. The same design life must be used for each alternative under comparison and for all cost categories under consideration. The potential for future obsolescence, that is, the potential that future changes may modify drainage system requirements, should be considered when selecting a project design life.

6.3.5 *Comprehensiveness*—The appropriate degree of precision and detail to use in an LCC analysis is dependent on the intended use of the analysis. A less comprehensive or detailed analysis may be sufficient for ranking many alternatives roughly, whereas a more comprehensive analysis may be necessary for selecting from among a few close alternatives. In any case, omitting significant factors from an LCC analysis diminishes the usefulness of the results.

6.3.6 *Sensitivity Analysis*—No analysis can be more precise than the accuracy of the data and assumptions used in the calculation. The LCC can be calculated for a range of assumptions when uncertainty exists regarding basic assumptions (for example, cost estimates, design life, discount rate, etc.). The results of these calculations will show the user the extent to which the results are sensitive to variations of the key assumptions.

6.4 *Compilation Data*—Compile the following data specific to each alternative under consideration:

6.4.1 *Initial Costs*—The estimated dollar amount of all costs required to bring the alternative system to a point of functional readiness.

6.4.2 *Material Service Life*—The number of years of service expected of the alternate under study. Material service life varies depending on the pipe material, environment, effluent, and application. Potential changes in environmental conditions that may affect the material service life should be considered. Job site tests, published reports, manufacturer product data, and local experience can be used to establish the service life for each material. If the material service life is shorter than the project design life (3.1.9), the analysis must include the future cost to extend the service life sufficiently through rehabilitation or replacement in order to at least equal the project design life.

6.4.3 *Future Costs*—Cost estimates should be made for all significant items that are estimated to be required to allow the drainage system to satisfy performance requirements over the project design life. Common costs (1.1) may be excluded without affecting the relative ranking of the alternatives under study. The cost estimates should be made in constant dollars (not including inflation) in the same time frame as the estimate of initial costs.

6.4.3.1 *Operating Cost*—An estimate of the annual cost for labor, power, and consumable materials and supplies required to operate a drainage system. Except for pumped systems, most drainage systems do not have significant annual operating costs.

6.4.3.2 *Maintenance Costs*—Cost estimates and the frequency of any inspection, cleaning, and minor repair necessary to keep the system operating at capacity during the project design life.

6.4.3.3 *Rehabilitation Costs*—The cost of major repairs to extend the material service life to equal or exceed the project design life. The years in which the rehabilitation are planned should be noted if more than one rehabilitation is anticipated.

6.4.3.4 *Replacement Cost*—The timing and cost estimate for complete replacement of any drainage system component. Care should be taken to determine whether the service life of the replaced material or component will at least equal the project design life. If not, rehabilitation or further replacement will be necessary.

6.4.3.5 *Terminal Value*—The value of the drainage system at the end of the project design life. The potential residual or salvage value of a drainage system is dependent on some of the factors considered when establishing the project design life. For example, if a storm sewer is being evaluated and a long (75 years) project design life is used, consideration should be given to the risk of future obsolescence. The higher the likelihood of functional obsolescence, the greater chance there may be no residual or salvage value. However, if it is expected that the material could be removed and either reused or sold, the net cash value (in constant dollars) represents the terminal value. It is not recommended that a residual value be used to reflect an economic value for any remaining material life in excess of the project design life. As an alternative, if it is felt that the functional requirements of the system under design are for an indefinite period, consideration should be given to increasing the project design life to an appropriately higher value, at which the residual value would not affect comparison of the various alternatives significantly.

6.5 *Computation of Life-Cycle Costs*— To compute the LCC for a drainage system, all relevant cost flows over the design life of the project are discounted back to the present and summed.

6.5.1 Find the present value (PV) of each cost category (for example, initial cost (IC), operating and maintenance (M), rehabilitation or repair (R), and terminal value (T)) using the appropriate discount formula in this section. Then sum these present values to find the PVLCC, for example:

$$PVLCC = PVIC + PVM + PVR - PVT \quad (2)$$

6.5.2 Initial costs are assumed in this practice to occur in the base year (year zero). No discounting is required.

6.5.3 Future costs expected to occur at a single point in time (for example, rehabilitation costs) can be discounted to present value by multiplying the estimated current cost of the item by the single present value factor as follows:

$$PVA_s = A_s\left(\frac{1}{1+d_r}\right)^n \quad (3)$$

where:

A_s = single amount,
d_r = real discount rate (Table 1), and
n = number of years from year zero to the time of the future single amount expenditure.

NOTE 1—The factor developed in this equation is generally known as the present value factor and can be found in financial tables of discount rates.

6.5.4 Future costs expected to occur in approximately the same amount (in constant dollars) from year to year (for example, operating or maintenance costs) can be discounted to present value as shown below:

$$PVA_r = A_r\frac{(1+d_r)^n - 1}{d_r(1+d_r)^n} \quad (4)$$

where:

A_r = recurring annual amount,
d_r = real discount rate (Table 1), and
n = number of years.

NOTE 2—The factor developed in this equation is generally referred to as the uniform present worth factor and can be found in financial tables of discount rates.

6.5.5 Example calculations are presented in Appendix X1.

6.6 *Comparison of Life-Cycle Costs*:

6.6.1 After calculating the LCC for each alternative, compare them to determine which alternative has the lowest LCC.

6.6.2 If the functional performance of the two alternatives is equal (or if performance differences are recognized in the computation), the alternative(s) with the lowest estimated LCC is economically preferred.

6.6.3 The effect of variations in key assumptions on LCCs can be developed by a sensitivity analysis. By varying the discount rate, material service life, and timing and magnitude of future costs, the decision maker can determine which factors have the greatest effect on the LCC of each alternative.

7. Keywords

7.1 cost analysis; discount rate; drainage systems; engineering economics; least cost; life-cycle cost; material service life; present value analysis; project design life

APPENDIX

(Nonmandatory Information)

X1. APPLICATION OF PRACTICE

X1.1 This example has been prepared to demonstrate the application of this practice. The example below is a calculation using the LLC mathematical formulas. Electronic calculators are widely available to help the user who wants to frequently make use of this practice.

X1.2 *Project Objectives*—A private developer has prepared plans for a storm drainage system to satisfy local code requirements. There are two alternatives, based on using different corrugated metal pipeline materials.

X1.3 *Basic Assumptions:*

Project design life	75 years
Discount rate (nominal)	10 %
Inflation rate	5 %
Common design costs	$150 000

X1.4 *Alternatives:*

	Material A	Material B
Material service life	60 years	100 years
Initial cost—Bid price for materials, installation, and inspection	$300 000	$345 000
Future costs—Annual inspection and maintenance	$6 000	$5 000
Partial invert rehabilitation in year 60 (base year $); life of rehabilitation is 25 years	$75 000	none
Terminal value—In base year $	none	$30 000

X1.5 *Discount Rate Calculations (See Table 1):*

$$d_r = \frac{1+d_n}{1+I} - 1 \text{ or } \frac{1+0.10}{1+0.05} - 1 = 0.048$$

where:

d_n = investor nominal discount rate, and
I = general inflation rate.

X1.6 *Life-Cycle Cost — Material A:*

X1.6.1 *Initial Cost*—$300 000.

X1.6.2 *Annual Inspection and Maintenance*:

$$PVA_r = \frac{A_r(1+d_r)^n - 1}{d_r(1+d_r)^n}$$

$$= \$6000\,\frac{(1+0.048)^{75} - 1}{0.048\,(1+0.048)^{75}}$$

$$= \$6000\,(20.215) \qquad \$121\,290$$

X1.6.3 *Rehabilitation:*

$$PVA_s = A_s\left(\frac{1}{1+d_r}\right)^n$$

$$= \$75\,000 \left(\frac{1}{1 + 0.048} \right)^{60}$$

$$= \$75\,000\ (0.060) \qquad \$4500$$

X1.6.4 *Total Life-Cycle Cost—Material A:*

Present value of:	
Initial cost	$300 000
Annual inspection and maintenance	121 290
Rehabilitation	4 500
Total life-cycle cost	$425 790
Rounded to	$426 000

X1.7 *Life Cycle Cost — Material B:*

X1.7.1 *Initial Cost*—$345 000.

X1.7.2 *Future Cost — Annual Inspection*:

$$PVA_r = A_r \frac{(1 + d_r)^n - 1}{d_r (1 + d_r)^n}$$

$$= \$5000\ (20.215) \qquad \$101\,075$$

X1.7.3 *Terminal Value*:

$$PVA_s = A_s \left(\frac{1}{1 + d_r} \right)^n$$

$$= -\$30\,000 \left(\frac{1}{1 + 0.048} \right)^{75}$$

$$= -30\,000\ (0.030) \qquad \$\text{–}900$$

X1.7.4 *Total Life-Cycle Cost—Material B:*

Present value of:	
Initial cost	$345 000
Annual inspection and maintenance	101 075
Rehabilitation	–900
Total life-cycle cost	$445 175
Rounded to	$445 000

X1.8 *Life-Cycle Cost Comparison:*

	Material A	Material B
LCC	$426 000	$445 000
Rank	1	2

SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A930 - 03) that may impact the use of this standard. (November 1, 2009)

(*1*) Dropped out of date referenced document OMB Circular No. A-94 and included a broad reference to federal and state guidelines or requirements.

(*2*) Added statement on availability of electronic calculators for frequent uses of this practice in X1.1.