Designation: C1131 – 10

Standard Practice for Least Cost (Life Cycle) Analysis of Concrete Culvert, Storm Sewer, and Sanitary Sewer Systems[1]

This standard is issued under the fixed designation C1131; 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 procedures for least cost (life cycle) analysis (LCA) of materials, systems, or structures proposed for use in the construction of concrete culvert, storm sewer, and sanitary sewer systems.

NOTE 1—As intended in this practice, examples of analyses include, but are not limited to the following: (*1*) materials-pipe linings and coatings, concrete wall thicknesses, cements, additives, etc.; (*2*) systems-circular pipe, box sections, multiple lines, force mains, etc.; and (*3*) structures-wet and dry wells, pump and lift stations, etc.

1.2 The LCA method includes costs associated with planning, engineering, construction (bid price), maintenance, rehabilitation, replacement, and cost deductions for any residual value at the end of the proposed project design life.

1.3 For each material, system, or structure, the LCA method determines in present value constant dollars, the total of all initial and future costs over the project design life, and deducts any residual value.

1.4 Major factors in the LCA method include project design life, service life, and relevant interest and inflation rates.

2. Terminology

2.1 *Definitions:*

2.1.1 *constant dollars*—dollars of uniform purchasing power exclusive of inflation or deflation.

2.1.1.1 *Discussion*—Constant dollars are costs stated at price levels for a specific reference year, usually the particular time that the LCA is being conducted.

2.1.2 *current dollars*—dollars of purchasing power in which actual prices are stated, including inflation or deflation.

2.1.2.1 *Discussion*—Current dollars are costs stated at price levels in effect whenever the costs are incurred. In the absence of inflation or deflation, current dollars are equal to constant dollars.

2.1.3 *direct costs*—the direct costs of excavation, removal, and disposal of existing materials, systems, or structures; installation and testing of replacements materials, systems or structures; backfill; surface restoration, traffic rerouting, safety, utility relocations, etc.; and additional future costs required by new land uses, population growth, etc.

2.1.4 *discount rate*—accounts for the time value of money and reflects the impartiality of paying or receiving a dollar now or at a future time.

2.1.4.1 *Discussion*—The discount rate is used to convert costs occurring at different times to equivalent costs at a common time. Discount rates may be expressed in nominal or real terms.

2.1.5 *future costs*—costs incurred after a project has been constructed and operating, such as maintenance, rehabilitation, and replacement costs.

2.1.6 *indirect costs*—the indirect costs to the owner that users pay in terms of delayed time.

2.1.7 *inflation rate*—an increase in the volume of money and credit relative to available goods and services resulting in a continuing rise in the general price level.

2.1.7.1 *Discussion*—In this practice, inflation refers to yearly change in the Producer Price Index (**1**).[2]

2.1.8 *interest rate*—the cost of borrowed money.

2.1.9 *maintenance costs*—the annual or periodic direct and indirect costs of keeping a material, system, or structure functioning for the project design life; such maintenance does not extend the service life of the material, system, or structure.

2.1.10 *nominal discount rate*—a discount rate that takes into account both the effects of inflation and the real earning potential of money invested over time.

2.1.10.1 *Discussion*—When future costs and values are expressed in current dollars, after having been adjusted for inflation, a nominal discount rate is used to convert the future costs and values to present value constant dollars. Users of this practice should consult with their accountant or client to determine the appropriate discount rate for a given project.

2.1.11 *original costs*—costs incurred in planning, designing, and constructing a project.

2.1.12 *project design life*—the number of years of useful life the material, system, or structure must provide.

2.1.13 *real discount rate*—a discount rate that takes into account only the real earning potential of money over time and is the differential between the interest and inflation rates.

[1] This practice is under the jurisdiction of ASTM Committee C13 on Concrete Pipe and is the direct responsibility of Subcommittee C13.05 on Special Projects.
Current edition approved Dec. 1, 2010. Published January 2011. Originally approved in 1995. Last previous edition approved in 2007 as C1131 – 95 (2007). DOI: 10.1520/C1131–10.

[2] The boldface numbers refer to the list of references at the end of the standard.

2.1.13.1 *Discussion*—When future costs and values are expressed in future constant dollars, a real discount rate is used to convert constant dollars to present value dollars. Life cycle economic analyses conducted in constant dollars and a real discount rate are often preferred to similar analyses conducted in current dollars using nominal discount rates because no forecast of the inflation rate is required.

2.1.14 *rehabilitation costs*—the direct and indirect costs of rehabilitating a material, system, or structure to extend the service life of the material, system, or structure.

2.1.15 *replacement costs*—the direct and indirect costs of replacing a material, system, or structure before the end of the project design life, so it will again function as originally intended.

2.1.16 *residual value*—the remaining value of the material, system, or structure at the end of the project design life.

2.1.17 *service life*—the number of years of service a material, system, or structure will provide before rehabilitation or replacement is required.

2.1.17.1 *Discussion*—Project design life and service life are usually established by the owner or controlling agency.

3. Significance and Use

3.1 The significance of the LCA method is that it is a comprehensive technique for taking into account all relevant monetary values over the project design life and provides a measure of the total cost of the material, system, or structure.

3.2 The LCA method can be effectively applied in both the preconstruction and bid stages of projects. After bids are taken, real costs can be used instead of estimates.

4. Procedures

4.1 The procedures for determining the LCA of a material, system, or structure can be summarized in five basic steps.

4.1.1 *Identify Objective, Alternatives, and Constraints*.

4.1.2 *Establish Basic Criteria*.

4.1.3 *Compile Data*.

4.1.4 *Compute LCA for Each Material, System, or Structure*.

4.1.5 *Evaluate Results*.

4.2 *Objectives, Alternatives, and Constraints*—Establish the specific objectives of the project and identify alternative ways of accomplishing the objectives. For example, alternatives for a sanitary sewer system may include a gravity flow system versus a gravity flow system with life stations versus a single force main. Identify constraints, such as maximum culvert head or tail water, maximum and minimum slopes and depths of burial, installation methods, etc.

4.3 *Criteria*—Establish basic criteria that should be followed in applying the LCA method, including project design life; the material, system, or structure service life; direct and indirect costs and timing of maintenance, rehabilitation and replacement; real or nominal discount rate; and the comprehensiveness of the LCA evaluation.

4.4 *Compile Data*—Compile basic data required to compute the LCA of potential alternatives, including costs of planning, design, engineering and construction; maintenance costs; rehabilitation costs; replacement costs; residual values; and the time periods for all future costs.

4.5 *Compute LCA*—The LCA of a material, system, or structure can be formulated in simple terms with all costs and values in present value constant dollars:

$$LCA = C - S + \Sigma(M + N + R) \quad (1)$$

where:

C = original cost,
S = residual value,
M = maintenance cost,
N = rehabilitation cost, and
R = direct and indirect replacement cost.

4.5.1 *Original Cost*—Original cost is defined in Section 2 and is normally developed from the engineer's estimate or is the actual bid price. A material, system, or structure may have a service life longer than the project design life and, consequently, would have a residual future current dollar value, which must be discounted back to a present constant dollar value, and subtracted from the original cost. Since maintenance, rehabilitation, and replacement costs may be incurred several times during the life of the project, the future current dollar value of each occurrence must be discounted back to a present constant dollar value and the values summed.

4.5.2 *Future Costs*—Future costs are normally estimated in constant dollar values, which are then converted to future current dollar values by an inflation factor and then discounted back to present constant dollar values by an interest factor:

$$FV = A\,(1 + I)^n \quad (2)$$

where:

FV = future current dollar value,
A = constant dollar value,
I = inflation rate, and
n = number of years in the future at which costs are incurred.

$$PV = \frac{FV}{(1 + i)^n} \quad (3)$$

where:

PV = present constant dollar value, and
i = interest or nominal discount rate.

Combining Eq 2 and Eq 3:

$$PV = A\left(\frac{1 + I}{1 + i}\right)^n \quad (4)$$

Eq 4 is usable, but requires assumptions of both interest and inflation rates. Although interest and inflation rates can vary widely, historical records indicate that the differential between interest and inflation rates has been relatively stable over the long term. Therefore, by defining an inflation/interest factor, F, as:

$$F = \left(\frac{1 + I}{1 + i}\right) \quad (5)$$

where:

F = inflation/interest factor.

Restating Eq 4:

$$PV = A\,(F)^n \quad (6)$$

The inflation/interest factor is virtually constant for specific differentials between interest and inflation rates. Therefore,