NRC·CNRC

NRC Publications Archive
Archives des publications du CNRC

Buildings and life-cycle costing

Rakhra, A. S.

For the publisher's version, please access the DOI link below./ Pour consulter la version de l'éditeur, utilisez le lien DOI ci-dessous.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40000755
Canadian Building Digest, 1980-07-01

NRC Publications Archive Record / Notice des Archives des publications du CNRC :
https://nrc-publications.canada.ca/eng/view/object/?id=448ca1d4-9423-42f3-b01e-9dab12dc7985
https://publications-cnrc.canada.ca/fra/voir/objet/?id=448ca1d4-9423-42f3-b01e-9dab12dc7985

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at
https://nrc-publications.canada.ca/eng/copyright
READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site
https://publications-cnrc.canada.ca/fra/droits
LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

Questions? Contact the NRC Publications Archive team at
PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

Vous avez des questions? Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.

National Research Council Canada   Conseil national de recherches Canada

Canada

Canadian Building Digest
Division of Building Research, National Research Council Canada

CBD-212

Buildings and Life-Cycle Costing

Please note

This publication is a part of a discontinued series and is archived here as an historical reference. Readers should consult design and regulatory experts for guidance on the applicability of the information to current construction practice.

Originally published July 1980.

A.S. Rakhra

Now that the cost of energy is a major component of building operating costs, there is a growing interest in total building-related costs over the lifetime of a structure. An economic evaluation of these costs is necessary to give those involved in the design and ownership of a building some basis for selecting the best investment in buildings or building systems.

Several methods have been used to evaluate the economic performance of investment projects over a period of time. Life-cycle costing (LCC) is one method now being widely used for such an evaluation of building investment projects. The purpose of this Digest is to explain, in general terms, the concept, technique, and assumptions of LCC. A brief discussion of some of its limitations is also included.

Life-Cycle Costing: An Overview

The term "Life-Cycle Costing" is quite broad and encompasses all those techniques* that take into account both initial costs and future costs and benefits (savings) of an investment over some period of time. They differ, however, in their applications which depend on various purposes of investment projects.[1] The total lifecycle cost (TLCC) is one of these techniques which will be emphasized in this Digest.

TLCC, as applied to the building activity, is a method of evaluating alternative building investment projects based on initial. operating and maintenance costs over the economic life of the project. For new buildings the TLCC technique is used to evaluate (or rank) the options concerning design, sites, and materials on the basis of total life-cycle costs. Its application to existing buildings involves: 1. comparison of total life-cycle costs and savings of rehabilitating the existing building vis-à-vis redeveloping it, i.e., tearing it down and rebuilding it; 2. determining how much of any given retrofitting measure or a combination of various retrofitting measures should be used in order to achieve maximum savings, given certain constraints of budget, level of amenity, etc.; and 3. determining which method of retrofitting or rehabilitating a building be used to achieve maximum savings from a given level of investment costs.

The basic costing equation for TLCC can be expressed as follows:

LCC = Total first costs plus all future costs (operating, maintenance, repair and replacement costs and functional-use costs) minus salvage value (i.e., value of an asset at the end of economic life or study period).

First costs are made up of all investment costs directly related to the project, including land costs and those associated with design, installation of services and construction, including future costs. They can be divided into two categories: energy costs. which include operating costs to cool, heat, and light the building, and non-energy costs comprising maintenance, repair, and replacement costs. Future non-energy costs may include functional-use costs (those incurred when the occupancy of a building changes or support systems are altered or updated). And there may be some costs resulting from changes made in compliance with building codes and standards. As life-cycle costs are spread over many years they must be converted to a common value (present or annual value) in order to make them comparable over a period of time. In converting future values to present values, "discounting" is performed by applying interest (discount) formulae to the estimated costs or benefits of a given investment project. The main idea behind discounting is that it should reflect the fact that today's money is worth more than tomorrow's, i.e., it can earn interest. This interest rate must be specified before LCC analysis is carried out. Assumptions must also be specified regarding the economic life of building components, inflation rate, future energy, and non-energy cost escalation rates. Before discounting, values of future flows of costs and savings should he converted to constant dollars to remove the effect of inflation and to make their comparison meaningful over a period of time.

To be able to decide which project is the most cost effective, one must assemble the information required to determine and evaluate the options. These are determined by specifying (a) the objectives, e.g., desired level of thermal comfort; (b) the constraints, which may include safety, aesthetics, or efficiency of users of facilities; and (c) the assumptions, and then calculating and comparing the total life-cycle costs of various alternatives.

In situations where the investor is confronted with several building investment alternatives, e.g., heating by conventional vs solar/conventional methods, the one with the lowest total life-cycle costs and which, at the same time, satisfies the investor's objectives and constraints, should be chosen. If there is only one investment project and the problem is to determine the efficient level of investment, e.g., investment in insulation, it is profitable to continue investing as long as the total life-cycle cost falls within an additional level of investment. The most economical level of investment will be determined at a point where the total life-cycle cost is minimized. Finally, in cases where the decision is to be made with regard to whether to invest at all, e.g., a decision to insulate the building, the criterion would be that total life-cycle costs must be lower with investment than without investment.

Depending on the objectives and the type of investment projects, other LCC-related measures such as internal rate of return (the interest rate for which the total discounted benefits from an investment equal its total discounted costs) and payback period (the period required for an investment to recover the investment cost, taking into account changes in the value of money resulting from "inflation" and changes in "time") can also be used to determine the most efficient level of investment.

Investment would be economical if the internal rate of return were greater than that minimally accepted by the investor; under the discounted payback period analysis, it would be economical if the time required to recover an investment were lower than the expected life of a building project.

Before finally selecting an investment project, it is sometimes desirable to test its economic feasibility based on alternative values of key parameters uncertain in the future, e.g., life of the building, energy price escalation rate, and discount rate. It is also important to know the value or range of values of parameters that affect the LCC analysis. This can be done by recomputing the LCC measure for minimum and maximum values of the parameters in question, using a technique called "sensitivity analysis." This informs the decision-maker of the consequences associated with uncertainties in the data.

In brief, an LCC analysis requires the following steps:

1. Specify the objectives and constraints of the analysis.
2. Identify options to achieve the objectives.
3. Specify various assumptions regarding discount rate, inflation rate. economic life, etc.

4. Identify and estimate relevant costs.
5. Convert all costs into constant dollars and to a common base.
6. Compare the total life-cycle costs for each option and select the one with the minimum total costs.
7. Analyze the results for sensitivity to the initial assumptions.

Application of TLCC

Although it is not feasible to present specific examples of TLCC in this Digest, many are available in the literature.[1-4] The following applications are the most common.

Building Design. -- The optimum building design, according to TLCC technique, is that which minimizes initial plus discounted future costs of the building over its lifetime. Different designs providing the same level of service can be ranked and the one with the lowest life-cycle costs chosen.

The optimum housing design has many components (initial costs, maintenance costs, operating costs, etc.), each involving several parameters. To determine the optimum design, one has to minimize the life-cycle costs with respect to each of these components. The sum total of each optimum-design component will not necessarily give the over-all optimum design because "tradeoffs" may exist among the various design components.

Energy Conservation. -- In the context of energy conservation, the TLCC technique may be used to answer the following questions:
(1) how to select the best energy conservation feature among various options, (2) how much investment should be made in a single energy conservation feature, and (3) which is the most desirable combination of various energy conservation features.

1. A choice can be made among various options of the energy conservation measure that fetches maximum savings in the form of reduction in the life-cycle costs. For instance, a choice can be made between double-glazed and triple-glazed windows. Similarly, a life-cycle cost comparison can be made between a solar heating system and a conventional heating system. The one that minimizes the life-cycle costs of providing a given level of comfort should be chosen.
2. This application of the TLCC technique to energy conservation is related to determining the optimum level of the chosen energy conservation measure. For example, if it is decided to retrofit an existing building through attic insulation, the optimum level of insulation resistance for a given heating (or cooling) index value would be the point at which the total life-cycle costs are minimum.
3. Sometimes energy conservation measures involve the combination of several features. The best combination can be determined by evaluating the net life-cycle costing effects associated with successively increasing amounts of other energy conservation measures. The best combination is found by substituting among the choices until each is used to the level at which its additional contribution to energy cost reduction per additional dollar is just equal to that for all the other options.

Rehabilitation and TLCC

. -- The TLCC technique can be used to help decide whether a building should be rehabilitated or replaced by a new one. If the decision is to rehabilitate, the technique can further be used in determining the most economical method of rehabilitating a building, given certain budgetary and safety constraints.

Building Codes and TLCC. -- The TLCC technique has been used to evaluate the impact of building codes and regulations by comparing life-cycle benefits and costs resulting from a specific code provision.[4] Several efforts to study the economic impact of building codes are underway; they all are confronted with the difficult problem of estimating the value of human life and safety.

TLC -- Problems of Applications. -- The TLCC technique is not free of problems. Broadly speaking, they are of two types: those of costing and availability of data and of prediction.

Estimating Costs. -- The first problem associated with TLCC technique is the difficulty of estimating lifetime costs. Determining initial costs is not difficult, compared with the estimation of future maintenance costs (including minor repair and replacement costs) and operation costs. The cost of maintaining equipment, machinery or building can be divided into "direct" and "indirect" costs. Direct costs, those incurred on the day-to-day maintenance of a building. are much less difficult to estimate than indirect costs incurred on the purchase of machinery or equipment to reduce maintenance expense. Indirect maintenance costs include revenue lost as a result of loss of production or service during any period of "shut-down" and are not easy to define or to estimate, especially for housing services.

External factors like the oil embargo of 1973 and the accompanying rise in fuel prices may frustrate efforts to estimate operating costs of heating and cooling systems. Finally, obsolescence, a process of not only changing technology but of changing tastes and fashions, can make it difficult to estimate operating costs objectively.

Prediction Errors. -- The process of predicting the various costs and savings is fraught with errors. The root cause is uncertainty of the future. Prediction errors can broadly be classified as measurement and sampling errors, and errors in assumptions. Errors of measurement can occur as a result of differences in measurement units; sampling errors result from the fact that a sample may not be representative of its population.

Prediction errors may occur as a result of incorrect assumptions about discount rate, inflation rates, life of building and materials, study period, timing of repair and replacement costs, energy escalation rate, obsolescence rate, economic life and salvage value. For discount rate, the usual practice of using market interest rate of borrowed funds and assuming that it will be constant over the life-cycle of the building ignores the possibility of variations resulting from changes in monetary and fiscal policies.

Prediction of inflation rates over a period of 30 to 40 years is another factor contributing to prediction errors. The general approach with life-cycle studies is to relate all prices to a common base. In doing so, effects of inflation are ignored on the assumption that all costs will inflate at the same rate. This, however, is not always true. It is unlikely that labour costs, material costs and energy costs will change at exactly the same rate. As various cost elements (capital, maintenance and running) vary with regard to labour/material components, it cannot be assumed that the same inflation rate will prevail in each case or that the results derived therefrom will be equally distorted.

Another difficult area in LCC forecasting is related to determining the life of building materials and components. Theoretically it can be related to observed probability of failure. In practice, however, it is difficult to obtain such information and it is seldom complete, as it does not record success or number of components or materials exposed to risk. Related to this prediction problem is the difficulty of forecasting the timing of repair and replacement costs.

Concluding Remarks

LCC is a valuable method of tracing the cost consequences of various alternative investment projects with long life spans. It is now used in both the public and private sectors as a tool to select the best investment option for new construction and to determine the feasibility of alternative systems in building retrofits. But because the application of LCC requires prior specification of several parameters and a considerable amount of prediction about them, the limitations of the method must be clearly understood. Efforts should be made to improve its value by developing a data bank on the various components of the total life-cycle costs.

References

1. Marshall, H. E. and R. T. Ruegg. Simplified energy design economics. Edited and illustrated by Forest Wilson, Centre for Building Technology, National Bureau of Standards, Washington, D.C., 1978.
2. Ruegg, R., et al. Life-cycle costing, a guide for selecting energy projects for public buildings. National Bureau of Standards, Building Science Series, No. 113, Washington, D.C., 1978.
3. Marshall, H. E. and R. T. Ruegg, Energy conservation through life-cycle costing. Journal of Architectural Education, Vol. XXX, No. 3, Feb. 1977, p. 42-53.
4. McConnaughey, J. S. Jr. An economic analysis of building code impacts: a suggested approach. National Bureau of Standards, NBSIR78-1528, Washington, D.C., 1978.

---

* These techniques include: total life cycle cost (TLCC), the benefit-cost or savings-to-investment ratio, the internal rate of return, and the payback period.