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ABSTRACT
Life-cycle costing is a management tool that may assist school administrators in making cost-effective decisions about building and improving school facilities. Life-cycle costing is defined as determining the total cost of building construction, operation, and maintenance over the assumed life of the building. An overview of the recent literature on this topic is presented along with 15 abstracts from the ERIC system. (Author/MLF)

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LIFE-CYCLE COSTING
By Philip Piele and Darrell Wright

The continually rising costs of constructing, operating, and maintaining school buildings, added to the constant demand from the taxpaying public to reduce school taxes, create a dilemma for the managers of public schools. The evidence can be found in the cost-study indexes and the number of school bond proposals and budget elections being defeated across America each year.

Concerned school managers seek ways to reduce costs while maintaining high standards of quality that will not hinder the educational development of students. Life-cycle costing (and the related concepts of cost-benefit analysis and value analysis) is a management tool that may assist school managers caught in the bind of the rising costs-reduce taxes syndrome.

Life-cycle costing can be defined as determining the total cost of building construction, operation, and maintenance over the assumed life of the building. A list of factors to be considered in life-cycle costing should include (1) the initial capital costs, which include costs of actual construction, architectural and engineering fees, furniture and equipment, land, site work, and landscaping; (2) annual costs, which are totals of expenses for major renovation, alterations, replacements, physical plant administration, maintenance, utilities, landscape, and grounds maintenance; and (3) finance, interest, and bond sales charges related to initial construction.

A Building Systems Information Clearinghouse (BSIC) publication states that life-cycle costing provides a reasonable estimate of the cost of a building or element of a building over a given period of time. The forecasting of this estimate requires knowledge of first cost, bond sale conditions, fuel and utility consumption rates, and personnel and maintenance costs.

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Cost-benefit analysis and value analysis are related to life-cycle costing, but, unlike life-cycle costing, these two concepts include an estimate of value or benefit to the client. Life-cycle costing does not include any estimates that require subjective judgments of value.

Although the definition is not complex, actual calculation of life-cycle costs can be very complex. Problems involve the forecasting of annual costs over the life-span of the building. The initial cost data are normally readily available, but determining the total cost of fuel, the rate of fuel consumption, personnel costs in times of rising wages, and needed future remodeling can be a difficult task. Fortunately, suggestions, guidelines, and worksheets that facilitate the task are available in the literature.

Life-cycle costing is frequently related to energy conservation and heating, ventilating, and air conditioning (HVAC) systems. During the initial building construction, life-cycle costing methods can be used effectively to compare the initial construction costs and total lifetime costs. Bids may be compared on a basis of the totul life cost of the building. Results may reveal that the lowest initial costs are not the most economical over the entire life-span of the building. Case studies have shown instances where a higher initial construction cost actually resulted in lifetime savings.

The pressing needs for energy conservation, the rising cost of fuel, and the need to reduce and avoid pollution require that the selection of energy systems be based on lifetime data rather than on initial costs alone. Through life-cycle costing, a school district can begin a cost-saving and energy-reduction program that is responsive to the demands of taxpayers and conservationists without any reduction in the educational opportunity available to students.

Blake, Robert. "Life Cycle Costing as an Aid in Decision Making." *Building Research*, 10, 3-4 (July-December 1973), pp. 17-20. EJ 092 665.

"The basic strategy inherent in the notion of life-cycle budgeting and life-cycle costing is to articulate the enormously complex issues involved in generating some new operational activity and the facility needed to shelter that activity, in three broad categories: cost, time, quality," Blake states, initiating this article, which contends that such a strategy leads to more rational decision-making with respect to costs.

Cost categories are listed as program operation, facility operations, facility alterations, denial of facility use, interest, facility and equipment. Time factors listed are facility life, program life, facility delivery period, and amortization period, all in terms of years. Quality measures are expressed in narrative statements regarding the performance requirements (what is needed), the performance criteria (how much is needed), and the tests (simulations of actual conditions).

The application of life-cycle costing occurs when the yearly ownership and operations costs are summarized, relating each year's cost to the present in terms of a discount factor.

Graphic figures are included to depict the processes in the life-cycle costing concept.

Bowen, Brian. "Design Evaluation Techniques. P/A Building Cost File." *Progressive Architecture*, 55, 5 (May 1974), pp. 116-118. EJ 096 083.

To clarify definitions and separate concepts, Bowen draws distinctions among life-cycle costing, value analysis, and cost-benefit analysis. Life-cycle costing is a technique for calculating initial costs, operating and maintenance expenses, and renovation and replacement costs of a building over the assumed life of the building. The applications for life-cycle costing are listed as comparing (1) alternative methods of providing space needs, (2) long-term implications of alternative system designs, (3) costs of construction materials, and (4) costs of operational systems.

Bowen discusses four concepts—life-cycle, value analysis, cost-benefit, and calculation of capital costs—in relation to durability, operating and maintenance expenses, and appraisal quality.

The author suggests that an essential part of any life-cycle/value analysis program is to bring about closer cooperation between design/construction teams and operation/maintenance people to achieve better monitoring during the building life in order to improve future designs.

(Previous articles by Bowen in *Progressive Architecture* issues for July 1973, October 1973, and February 1974 discuss building costs, cost analysis, and cost planning.)

Building Systems Information Clearinghouse. *Case Studies of Energy Use: Elementary and Secondary Schools. BSIC/*

EFL Energy Workbook No. 1. Menlo Park, California: 1974. 24 pages. ED 096 733.

The first of a planned series of energy-use case studies, this report presents analyses of five public school energy-use practices. One study reports means of reducing energy consumption in existing school buildings and methods of estimating the energy and cost effects of various proposed conservation strategies. Tables are included to show computer simulation comparisons.

A second study reports the construction of a new building, with energy consumption a major factor in cost comparisons. Findings reveal that all estimated initial costs for construction were the same, which highlights the need for analyzing energy conservation ability in the life-cycle costing process.

Four other studies present energy consumption comparisons of various conservation strategies.

A BSIC conclusion states that life-cost analysis is particularly sensitive to the estimates of future operating costs. Short-range initial costs can be more accurately produced, whereas the unpredictability of fuel costs makes long-range cost analysis more difficult.

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> Also available from EDRS. MF \$0.76 HC \$1.58. Specify ED number.

Building Systems Information Clearinghouse. *Energy Conservation and the Building Shell. BSIC/EFL Energy Workbook: Section 1.* Menlo Park, California: 1974. 34 pages. ED 094 477.

Factors that affect energy consumption and design ideas that lead to conservation of energy are the focus of this report.

Life-cycle costing, in a simplified form, is presented as the BSIC Preliminary Analysis Method. The method provides a reasonable estimate of the cost of a building or element of a building over a given period; of course, data for estimating first costs, bond sale conditions, fuel and utility consumption rates, and maintenance and personnel costs must be available. It is also a reasonable method of comparing alternatives, taking into account operating cost and fuel consumption differences.

OTHER TITLES IN THIS SERIES

1. Enrollment Forecasting
2. Evaluating the Existing School Plant
3. Computerized Planning Methods
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6. Educational Specifications
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Example forms for preparing a life-cycle cost analysis are included with sample worksheets completed for illustrative purposes.

> Order copies from Educational Facilities Laboratories, Inc., 850 Third Avenue, New York, New York 10022. \$3.00.
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Clark, George W. "Life Cycle Cost-Benefit Analysis for Electric Lighting." *Building Research,* 10, 3-4 (July-December 1973), pp. 24-28. EJ 092 667.

Life-cycle costing for electric lighting can be analyzed with respect to the impact and influence on people, and to good owning and operating practices of the physical elements. Citing the difficulty in determining proper illumination levels, it is concluded that evidence indicates that both the quality and quantity of illumination affect productivity, which contributes to energy conservation. Thus, illumination levels should be considered as a part of the energy system wherein life-cycle costing is appropriately applied.

Guides for determining appropriate illumination levels are selection of task, predetermination of the task location within the space, and establishment of the light loss factors. Life-cycle cost-benefit analysis suggests the possibility of nonuniform illumination, implying greater flexibility and versatility.

Operation control of lighting, lighting for heating, and maintenance discussions relating to life-cycle costing and cost-benefit analysis complete this article. The concluding idea suggests that life-cycle costing can help avoid trading off the quality of life.

Council of Ontario Universities. *Report of the Task Force: Building Life Costs. Building Blocks: Background Studies on the Development of a Capital Formula for Ontario. Volume 5.* Toronto, Ontario: 1973. 168 pages. ED 089 429.

Although claiming its investigation to be only preliminary with tentative conclusions, the Task Force on Building Life Costs presents life-cycle costing in depth and detail. Life costs are defined as the initial capital costs and the annual operation and maintenance costs, including major renovations, alterations, and replacements over the assumed life of the building.

Several problems of life costing are discussed: the lack of available data and the difficulties of determining the life of a building, converting past costs to current values, forecasting future costs, and converting future costs to current costs. A computer program was developed to handle life-cost calculations.

As an example of the problems and the type of results to be obtained, the life costs of the Faculty of Law Building, University of Windsor, were evaluated using the method of analysis suggested by the task force.

The second part of the report discusses cyclical renewal.

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Dell'Isola, A. J. "Facing Up to the Energy Crisis. Two Views." *Modern Schools*, (March 1974), pp. 4-6. EJ 092 728.

Outlining a new approach to fuel supply and selection for large school systems, Dell'Isola recommends that districts survey existing facilities to obtain realistic operating cost data. A study format for such a survey is provided.

Second, he provides a procedure to analyze historical information for each building, including first cost, annual operating and maintenance cost, break-even point, and system cost per square foot on first cost and annual operating cost. Formats are provided to guide this procedure.

Results of a recent study show the ability of life-cycle costing to compare systems. An HVAC system for a recently built systems high school was analyzed by life-cycle costing procedures, and the fifth lowest initial cost bidder provided the lowest cost of owning and operating the school over a 15-year period. The difference in fuel cost was the principal difference.

Reductions in costs and energy requirements can be realized when fuel selection is based on life-cycle costing procedures.

Dell'Isola, A. J. "Fuel Supply and Selection. CEFP Special Report No. 9. Energy Conservation: A New Challenge for Education." *CEFP Journal*, 11, 4 (July-August 1973), pp. 7-8. EJ 082 624.

This article is the same as the Dell'Isola piece in the previously cited article in *Modern Schools*, March 1974. This reference is included for those who may have access to the *CEFP Journal*.

Educational Facilities Laboratories. *The Economy of Energy Conservation in Educational Facilities. A Report.* New York: 1973. 85 pages. ED 082 321.

While presenting energy conservation as the major theme, this report begins and ends with life-cycle costing. Labeling the current tendency of awarding contracts on first-cost basis as a growing folly, this report states that over a building's lifetime, ill-considered economies in construction cost can prove expensive in the long run.

Life-cycle costing is thus emphasized as a key to realizing the cost savings related to conservation of energy. Using life-cycle costing to replace initial cost as the sole basis for contract awards for mechanical and other energy-consuming subsystems is one of four final recommendations.

Concluding the discussion, an appendix lists three techniques for computing life-cycle costs: benefit/cost analysis, time-to-recoup capital investment, and direct comparison of life-cycle costing for alternative systems of building or subsystems. These three techniques are explained and illustrated using actual cost comparison figures as examples.

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> Also available from EDRS. MF \$0.76 HC \$4.43. Specify ED number.

"The Energy Advisor . . . Planning New Schools." *Modern Schools*, (September 1974), pp. 12-13. EJ 104 129.

A clear statement of goals of energy conservation and the use of life-cycle costing, it is asserted, can combine with new building plans to reduce energy consumption up to 50 percent in comparison with traditional building processes.

New construction can provide the opportunity for energy savings with respect to compact building shape, multiuse occupancy, total energy, wall shading, automatic controls, improved mechanical design, and improved electrical design.

This article is based on an Educational Facilities Laboratories publication, *The Economy of Energy Conservation in Educational Facilities.*

Ensign, William L. "Options in Modernization of School Buildings." In *Recycling School Facilities, Summary of a Conference (Andover, Massachusetts, March 8, 1974.),* edited by Stephen J. Clarke, pp. 14-18. Newton, Massachusetts. New England School Development Council, 1974. 21 pages. ED 100 027.

A short article in a thin volume does not expand a definition of life-cycle costing but adds weight to the justification of the concept. Ensign, an architect, clearly indicates that school planners need to take a long-range view in determining whether to modernize, rehabilitate, or replace old school buildings. Life-cycle costing or value engineering is one process for making the long view possible.

Order copies from New England School Development Council, 55 Chapel Street, Newton, Massachusetts 02160. $0.50 members, $1.00 nonmembers.
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Roush, Larry F. "Energy Conservation for Public Office Buildings." *Building Research,* 10, 3-4 (July-December 1973), pp. 5-8. EJ 092 662.

Conservation means more than savings alone. With respect to energy, conservation is the best balance between the benefits and costs, a definition that indicates changes in traditional procedures and attitudes. One of the changes is the use of the life-cycle costing concept.

Three federal buildings were to be constructed in 1973 applying an integrated systems concept to high-rise construction based on performance specifications. The systems concept combines building components in an attempt to minimize operating costs. Bidders on the basic systems for these buildings were encouraged to use life-cycle costing techniques. The award was based on the cost of energy consumed over 40 years of the assumed building life.

To analyze bids, the cost for energy required for one year was multiplied by 40 and added to the system cost to determine the low bidder. The result suggests a reduction in energy usage without a loss of quality.

Stephan, Edward. "Use Life-Cycle Costing to Analyze Bids." *American School and University,* 47, 8 (April 1975), pp. 33-35. EJ 115 870.

Stephan provides several formulas for computing life-cycle costs, with criteria for selecting bids. A summary chart for an HVAC evaluation compares four separate systems and reveals the total annual cost over the life cycle.

An example from the author's experience illustrates the practical savings that can result from computing life-cycle costs; an investment was made in initially more expensive but potentially more efficient equipment.

"What Schools Are Doing about Economizing on Energy." *Nation's Schools,* 93, 1 (January 1974), pp. 39-44. EJ 089 420.

Included in this energy conservation article is an example of life-cycle costing in practice. The article claims that

[illegible] Tennessee High School Yearwood & Johnson Architects

use of life-cycle costing for awarding bids can result in savings on energy and low owning and operating costs. To illustrate application of the technique, the case of the new Chantilly High School, Fairfax County, Virginia, is presented.

Calculations revealed that the HVAC system selected through the life-cycle costing process would save $356,360 by 1993 when compared to the system with the lowest initial cost. The bidding process is explained and analyzed with an accompanying chart of comparative figures.

Fairfax County school officials plan to use life-cycle costing methods in future bidding for building materials in addition to HVAC systems.

Winders, Marvin S. "The Role of an Operations Consultant in Life Cycle Management." *Consulting Engineer*, 43, 2 (August 1974), pp. 103-105. EJ 102 559.

The rapid inflation of building construction costs is due mainly to energy cost and usage, higher labor wages, and system services and control sophistication. Given these conditions, Winders suggests an operations consultant be retained to provide life-cycle management resulting in maximum efficiency, profitability, and performance in a building project.

The operations consultant, working for the owner, can provide operations expertise in selection of building engineering systems, support of construction management, construction supervision, and continuity of the project life cycle; the consultant is available for life-cycle management throughout the construction project.

An operations consultant can reduce life-cycle costs for existing buildings by providing manpower and systems equipment scheduling, operating procedures and programming, preventative and maintenance direction, cost records and budgeting, and ongoing systems analysis. He also acts for the building manager to establish cost and systems control.

Case histories can show total life-cycle savings when operations consultants are employed by the owner.

Windheim, Lee S. "A Systems Morphology for Examining Energy Utilization in Buildings." *Building Research*, 10, 3-4 (July-December 1973), pp. 29-33. EJ 092 668.

A building, commercial or residential, is a delivery system, "a goal-seeking and purposeful entity," that is activated by energies—energy use that consumes 30 to 40 percent of the total national energy. The system called building may be visualized in six interactive parts: personnel, devices, procedures, space, site, and envelope. Life-cycle cost-benefit evaluation is concerned with this entire system. Dividing the six components into two subsets, activity subset (personnel, devices, procedures) and facility subset (space, site, envelope), architects and engineers may "conceptualize the dynamics of such energy flows through the facility subset and then analyze trade-offs with life-cycle cost/benefit value analysis . . . they may save up to 80 percent of the energies presently used in buildings."

This article, also, discusses the larger issues of energy conservation related to pollutions, delivery systems as a man/machine/environment goal-seeking system, and conservation as a means not an end. Life-cycle cost-benefit value analysis is suggested as an appropriate technique for assisting decisions on energy utilization.

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