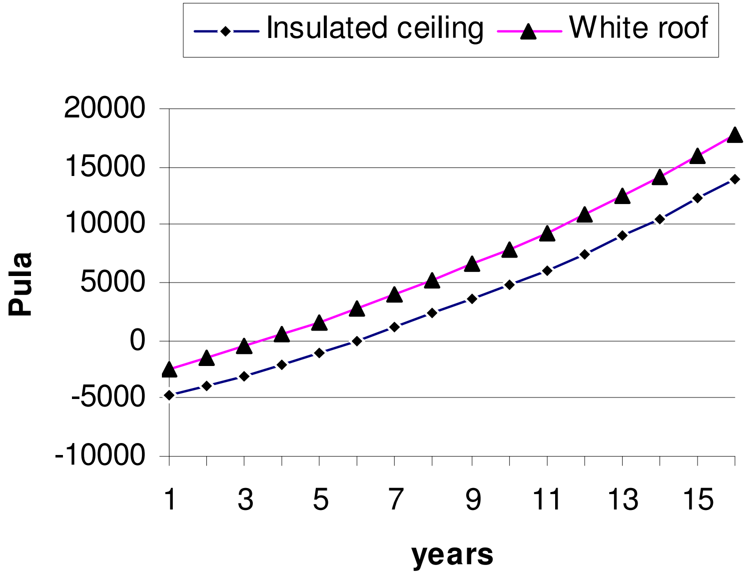
SECTION 12 LIFE-CYCLE COST ANALYSIS



ENERGY EFFICIENCY BUILDING DESIGN GUIDELINES FOR BOTSWANA

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ENERGY EFFICIENCY BUILDING DESIGN GUIDELINES FOR BOTSWANA

Sections:

CONTENTS

12. LIFE-CYCLE COST ANALYSIS

12.1. Summary

This Section gives an overview of life-cycle costing (LCC) as it is applied to building projects. The relevance of LCC to energy efficient building design in particular was discussed in **Section 5, Design and Construction Process**.

LCC is defined, and the opportunities and limitations of this costing system are considered.

One of a number of possible approaches to calculating LCC is described, with references to sources for more detailed information and instructions.

An example of the application of LCC analysis is described to illustrate how it may be used to assist in decision making at the design stage of a project.

12.2. Overview

12.2.1. Definition and description.

Life-cycle Costing is defined in this context as:

A method of cost analysis that estimates the total cost of a project over a period of time that includes both the construction cost and ongoing maintenance and operating costs.

LCC is one of a number of tools that can be used to assess the cost effectiveness of various investment options.

Others include:

- Simple Payback.
- Internal Rate of Return.
- Net Present Value.

Simple payback is a cost analysis method whereby the annual savings arising from an investment is estimated, and divided by the investment cost to give the number of years required to recover the cost of the investment. This may also be compared to the expected time to replacement of the system or component. For example, if a solar heater costs P12,000 and results in a saving of P1,000 per year and has an expected life to replacement of 10 years, the payback time is 12 years and it would not be financially viable to make the investment. If the annual savings is doubled (e.g. due to increase electricity cost), then the payback becomes 5 years and the investment is now viable.

Internal Rate of Return is the annualised return on investment, based on the amount saved in relation to the amount invested. This is compared with similar indicators, such as the interest rate that could have been earned in an investment account to determine whether the investment is cost effective.

Net Present Value is a method of assessing the present value of future costs and returns, using a ‘discount rate’ to quantify the relative value of having access to money now compared to having access to it in the future.

LCC is more complex than any one of these tools, in that it takes into consideration a greater number of relevant factors than the other methods. These include:

- Replacement cost for components or systems.
- Expected time to replacement.
- Maintenance costs.
- Variations in projected prices for energy and other inputs.
- Variations in projected interest rates.

12.2.2. Opportunities

Historically investment decisions relating to buildings have tended to be based on estimates of the initial construction cost, with little or no consideration for costs relating to operation and maintenance throughout the life of the building.

Sharply rising energy costs have highlighted the opportunity for overall savings in the life of a building that can be achieved by investing in more energy efficient solutions initially. Savings on other operating and maintenance costs can also be considered, e.g. using building finishes that do not need frequent re-painting.

LCC is a cost analysis tool that allows such factors to be quantified at the design stage, so that informed decisions can be made regarding the cost effectiveness of different possible design solutions.

In some building codes it is a requirement that LCC be applied at an early design stage to demonstrate that the building has been designed for minimum life-cycle cost. (e.g. Iowa Code 2001).

The development of software packages that allow for accurate simulation of the energy performance of buildings has greatly increased the effectiveness of LCC, as it is now relatively easy to predict the effect on annual energy cost of changes in the design of a building. This information is essential to allow accurate LCC analysis to be carried out.

12.2.3. Limitations

As with all predictive pastimes, the output from a LCC analysis is only as good as the input. It relies on a large number of assumptions, some of which may be quite accurate, and others that cannot be, since they are based on predictions of circumstances far into the future. With regard to energy cost, the most difficult predictions to make are those related to the future cost of energy supplies.

The decision as to how energy cost will change in the future may have a large impact on whether a particular intervention is cost effective or not in a life-cycle analysis.

Likewise, the costs of materials, labour, finance, etc need to be estimated for the full period under consideration, often 50 years or more, which obviously requires some very creative guesswork.

The task has been made somewhat easier in that standard sets of assumptions for many of these variables are available, e.g. from the USA government that are required to be used for LCC analysis that relates to government codes. This means that valid comparisons can be made between different projects. However, if the predictions are inaccurate or based on false assumptions regarding the future, then the wrong decisions may result for a large number of buildings.

Another problem lies in predicting the useful life of different components and relating these to the time frame for the analysis. Using a longer time frame, such as the life expectancy of the building has advantages in that it allows all costs and benefits related to the project to be considered, including cost of demolition, salvage value of materials, etc. However this time frame tends to be so long that sensible predictions of costs, discount rates, rental values etc. are unrealistic.

When shorter periods are used for the analysis, care must be taken to avoid errors arising from component replacement periods that are of a similar order to the analysis period.

12.3. Elements of Life-Cycle Cost Analysis.

12.3.1. Essentials.

A life-cycle cost analysis determines the estimated cost of all aspects of owning a building over a specified period of time. Often this is the anticipated life of the building to demolition, in which case the cost of disposing of the building may also be included. These costs are all reduced to Net Present Value (NPV), which is a measure of their value in today's currency (i.e. 2007 Pula value).

By reducing all costs and savings to NPV, the impact of inflation or deflation on value is removed, allowing comparisons between costs at different times in the future (or past).

The result of a LCC analysis is therefore the total cost of owning the building over the specified period, at today's prices. This is typically calculated for a number of alternative solutions. The results are then compared to show the relative benefits of the different alternatives. This information is then used to assist in making an informed choice between the alternative solutions.

12.3.2. Stages of LCC Analysis.

Essentially LCC analysis carried out in three stages as follows:

Stage 1.	Define data.
Stage 2.	Analysis.
Stage 3.	Evaluation of results.

12.3.3. Stage One – Define Data.

The first stage in performing a LCC analysis is to define the information that is needed for each option that is to be analysed.

The key data required are as follows:

- Construction cost.
- Financing cost.
- Recurrent operating costs.
  - Energy costs.
  - Non energy costs.
  - Maintenance costs.
  - Cyclical maintenance.
  - Repairs.
  - Equipment replacement costs.
- Taxation costs and benefits.
- Demolition and disposal cost.
- Income generated (typically impact on productivity or sales, sale of electricity to the grid, etc.)

In each case the present value of future costs must be estimated. This varies from current value due to two different factors.

One factor by which future costs must be adjusted is the inflation rate, or the change in price over time. Assuming that all costs change at the same rate over time, this can be disregarded, if the analysis is carried out on the basis of constant currency, e.g. in 2007 Pula.

Generally for LCC analysis of building projects it is assumed that costs other than energy costs change at much the same rate so that variations in inflation rate can be ignored. Energy costs however tend to fluctuate independently of general inflation, so an adjustment is made for the real rate of energy cost inflation, i.e. the rate at which energy cost changes relative to general costs.

The second factor by which future costs must be adjusted is the discount rate. This reflects the perceived difference in value of an investment made today, compared to value of the same investment being made in the future. It is generally related to the real interest rate, i.e. the rate by which interest on investments differs from the general inflation rate. Future costs are adjusted to present value by applying the discount rate over the period between the present and the time when the cost will be incurred.

Standard ‘real’ inflation rates for different forms of energy and standard discount rates are issued by the US government for use in LCC analysis for federal buildings, to ensure a uniform approach to LCC between different jurisdictions. These are available for download at:

http://www1.eere.energy.gov/femp/pdfs/ashb06.pdf

Currently the ‘real’ discount rate used for assessing Government investment projects in Botswana is 8.0%. (pers. comm.. Dr. K. Jefferis).

No official figures for future real inflation rates for energy sources are available in Botswana, so an informed estimate must be made.

For variables that are difficult to predict, such as future energy price variations it is helpful to check the sensitivity of the analysis to these variables by testing a number of different values (e.g. max, min and most likely) to see the impact on the results. This gives an indication of the confidence that can be applied to the results.

12.3.4. Stage Two – Analysis.

The second stage is to carry out the actual computation of life-cycle cost for each of the alternative scenarios that are being evaluated.

The basic equation for Life-Cycle Cost is shown below (from Fuller).

LCC = I + Repl — Res + E + W + OM&R + O

Definitions:
LCC = Total LCC in present-value (PV) dollars of a given alternative
I = PV investment costs (if incurred at base date, they need not be discounted)
Repl = PV capital replacement costs
Res = PV residual value (resale value, salvage value) less disposal costs
E = PV of energy costs
W = PV of water costs
OM&R = PV of non-fuel operating, maintenance and repair costs.
O = PV of other costs (benefits)

A negative value for other costs (‘O’) may be included to include a value for benefits relative to a base case, for example if increased lighting levels are expected to lead to productivity gains or increased turnover.

A large number of software packages are available that can perform the calculations of LCC, making life considerably easier for the analyst.

A very detailed book on LCC analysis is the ‘Life Cycle Costing Manual. NIST Handbook 135’. This is available for download from the US Dept. of Energy, Energy Efficiency and Renewable Energy.
(http://www.eere.energy.gov/buildings/)

12.3.5. Stage Three – Evaluation.

The final stage in a LCC analysis is to compare the results for the different cases that were analysed.

LCC cost is usually only one of a number of criteria that will be considered in making a choice between different options. LCC essentially quantifies the financial costs and benefits associated with each option. Other, non-financial factors may also need to be considered, such as aesthetics, access to finance (which may be dependant on availability of collateral, or budgetary limitations), availability of equipment, skills needed for operation and maintenance, and many other considerations.

For complex investment choices it is helpful to use a rational decision making tool, such as a matrix to assist in evaluating the options in accordance with all the criteria. This is done by assigning a value for each option against each criterion, say on a score of 1-5. Each criterion is then given a weighting depending on how important it is considered to be relative to the other criteria. The outcome is then a score for each option, the highest scoring option being the most valued. Such a tool can help to guide the decision making process, but is of course always limited by the quality of the decisions that are made in applying it.

12.4. Illustrative example.

A simple example of LCC analysis is provided to illustrate how the process works.

This example was calculated using Energy eVALUator, a simplified tool for life-cycle cost analysis from Energy Design Resources.

Energy eVALUator is a simple-to-use Windows-based program for calculating the life cycle benefits of investments in improved building design. Energy eVALUator is designed to analyze improvements that reduce energy cost, improve employee productivity, and enhance tenant satisfaction.

The tool is designed to help building owners, developers, tenants, architects, engineers, and facility managers by providing the financial information necessary for making decisions based on the economic merits of improved building design.

The example uses a typical classroom building for which an energy performance simulation has previously been carried out using DesignBuilder and Energy Plus software. LCC analysis is used to evaluate the cost implication of providing 100mm of ceiling insulation, or using white roof sheets to reduce energy cost.

12.4.1. Stage One – Define Data.

Item	**Baseline**	**Insulated Ceiling**	**White roof sheets**
Building floor area [m^2]	160	160	160
General inflation [%]	0	0	0
Electricity inflation [%]	5	5	5
Analysis period [yrs]	15	15	15
Project cost [P]	400,000	404,800	402,400
Discount rate [%]	8	8	8
Initial Energy expenses [P/yr]	4,330	3,505	3,440
Other operational expenses [P/yr]	1,792	1,792	1,792

Table 12.1 Input data for LCC.

The input data was determined as shown in Table 12.1

It was assumed that the construction cost was paid for without loan.

A discount rate of 8% was used, which is the recommended for government investment appraisals (see above).

The analysis was performed at current Pula prices to remove the effect of inflation from the comparison.

A differential inflation rate of 5% for energy costs was included to allow for energy costs to escalate at 5% more than other costs.

A 15 year period was selected for the analysis.

12.4.2. Stage Two – Analysis.

This data was input into a project in the eVALUator software package which performed the necessary calculations. Output reports were generated that compare the LCC for both the alternatives with the baseline case and also provide the simple payback periods.

The results were as follows:

Item	**Baseline**	**Insulated Ceiling**	**White roof sheets**
Analysis period [yrs]	15	15	15
Project cost [P]	400,000	404,800	402,400
Energy expenses [P]	52,229	42266	41,494
Non energy expenses [P]	15,339	15,339	15,339
Total life cycle costs [P]	**467,568**	**462,405**	**459,233**
Simple payback [yrs]	**-**	**5.8**	**2.7**

Table 12.2 Results of LCC.

Cash Flow reports were also produced and used to provide a graph showing the incremental savings achieved by both interventions. These illustrate the simple payback, which occurs were the incremental savings become zero as shown in Fig. 12.1

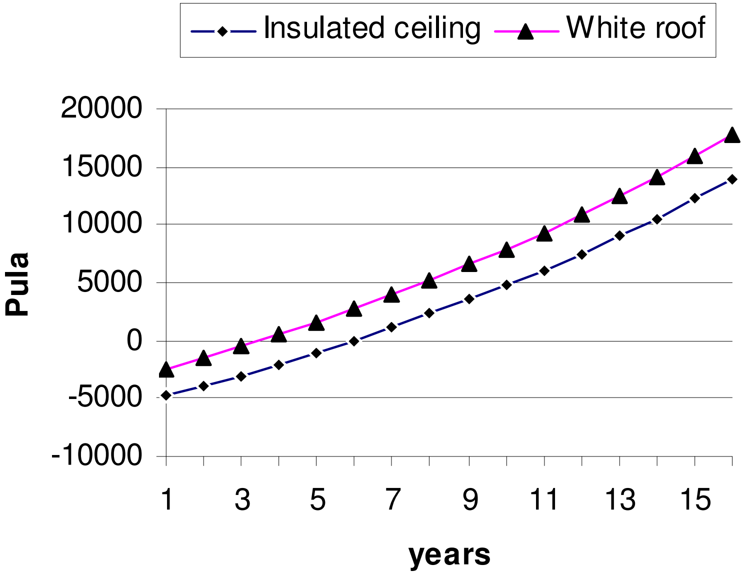

Fig. 12.1 Incremental savings.

12.4.1. Stage Three – Evaluation.

The results indicate that both ceiling insulation and using white roof sheets are cost effective strategies for reducing energy cost.

Using white coloured roof sheets is the preferred alternative, since it gives a shorter simple payback time, as well as a lower total life-cyle cost.

A further analysis could be carried out to determine the impact of combining both strategies, using white coloured roof sheets and providing insulation over the ceiling. This would first require a further energy simulation to determine the effect on energy consumption, before the LCC analysis can be carried out.

The strength of LCC analysis is that it allows a rational choice to be made, that would otherwise be based on hunches and guesswork. The weakness is the time and effort that it costs to carry out the analysis. This is greatly reduced by the availability of simple software tools that do most of the work.

12.5. Resource Material

12.5.1. Books and papers

Fuller, Sieglinde. Life-Cycle Cost Analysis (LCCA). National Institute of Standards and Technology (NIST) (http://www.wbdg.org/design/lcca.php)

Fuller, Sieglinde and Petersen, Steven. Life Cycle Costing Manual for the Federal Energy Management Program. NIST Handbook 135. 1995 edition. US Dept. of Energy.

Rushing, Amy S. and Fuller, Sieglinde K. Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis - April 2006 Annual Supplement to NIST Handbook 135 and NBS Special Publication 709

12.5.2. Websites

EDR. Energy Design Resources
. http://www.energydesignresources.com/

US Dept. of Energy, Energy Efficiency and Renewable Energy.
http://www.eere.energy.gov/buildings/

WBDG Whole Building Design Group
http://www.wbdg.org