LIFE CYCLE COSTING AND COST-EFFECTIVE DESIGN SOLUTIONS

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LIFE CYCLE COSTING

Introduction

According to Ruegg and Marshall[1] economic optimisation is the process whereby economic analysis is applied to determine the most economically efficient or cost-effective choice among alternatives. Moreover, the attainment of optimum economic efficiency reflects a fundamental goal of the majority of investors. Whereas traditional economic evaluation methods offer varying degrees of proficiency in determining optimum investment desirability, they fail to identify and evaluate the explicit relationships between capital costs and operating expenses. These inadequacies are especially relevant when viewed from the perspective of property investment evaluation. Recognising the intimate links between initial acquisition costs and subsequent running costs is fundamental to establishing the most cost-effective property development solution. Life Cycle Costing (LCC) represents a financial assessment technique whereby these issues are addressed.

LCC as a general management technique is not new. The process is acknowledged as a well established evaluation concept. Robinson[2] and Blanchard[3] remark that proven general business principles, which have been used in industry and commerce for years, underpin the method. Marshall[4] notes that LCC has traditionally been used by the United States government for large projects and currently most U.S. government agencies are required to employ formal life cycle evaluation methods. Notwithstanding the perceived benefits, widespread application of LCC is not universal. The resistance to implementing LCC is recognised by Ashworth and Au-Yeung[5] who reveal that, although the Royal Institution of Chartered Surveyors (Quantity Surveyors' Division) has consistently supported the use of the technique in practice, there appears to be a reluctance on the part of United Kingdom practitioners to implement LCC services. According to Norman[6] the primary causes for this limited application may be attributed to the following:

(i) A lack of reliable data,
(ii) A perception that, because it is essentially a forecasting system, LCC delivers questionable conclusions and is therefore inappropriate for decision-making, and
(iii) The precise nature of LCC computations removes the scope for managerial discretion.

Various terms are applied to identify the technique of LCC. These include costs-in-use, terotechnology, engineering economics and cost benefit studies. Although authors such as Blanchard[7], Ruegg and Marshall[8], Flanagan et al.[9], and Dell'isola and Kirk[10] accept LCC as a valid method of ensuring design efficiency optimisation, the approach has its detractors. Lenard et al.[11] challenge the merits of the procedure employed to evaluate life cycle costs. Drake[12] is more emphatic in his objections, while Grover and Grover[13] emphasise the consistency problems in LCC appraisals.

Definition

Although employed in the decision-making process in a number of industries, LCC is examined in this paper specifically in terms of its relevance to property development evaluation. LCC as applied to building activity is the term employed to portray a financial appraisal technique that permits comparative evaluation of building projects and/or components/systems constituting the physical asset. The life cycle cost of an asset subsequent running costs and final disposal costs or income.

Whilst authors such as Kerr and Capper[14] and Bejrum and Haugen[15] refer to income considerations, the LCC technique is generally promoted as a cost concept reflecting the cost consequences of design decisions. For instance, Ruegg and Marshall[16] identify LCC as a method used to evaluate alternatives which compete primarily on the basis of costs. A similar interpretation is advanced by the Royal Institution of Chartered Surveyors[17]. They introduce LCC as a technique that takes into account the total costs that a project imposes upon a client during the whole of its life. Within these stringent definitions, emphasis is clearly placed on cost-effectiveness and income benefits are specifically excluded from the computation procedure.

In essence LCC may be defined as

> *A financial appraisal technique that permits valid comparative evaluations of available alternative possibilities based on time-phased costs over a specific investment period in order to arrive at the optimum cost-effective solution.'*

LCC functions

Although many basic design decisions are subject to outside influences such as town planning regulations, and are not candidates for life cycle costing, the majority have multiple options each with its own economic consequence. Unless these alternatives are clearly defined, incorrect decisions may be made by the failure to recognise possible substitutes. Even if several alternatives are considered, ineffective selections may result as a consequence of not having considered the best solution. A poor alternative will inevitably appear the best selection if compared with alternatives that are even worse.

An LCC study provides a framework for selecting the optimum alternative from among mutually exclusive options which may differ with respect to both initial and running costs. The technique facilitates the comparison of all relevant costs by converting them to equal terms at common points in time. LCC employed at the inception stage of a development may be used as a technique for determining whether or not to build, or for evaluating alternative building developments on the basis of initial, operating and maintenance costs over the economic life of the project.

IMPLEMENTATION OF THE TECHNIQUE

Implementation process

LCC represents a logical method of evaluating developments with respect to the design of complete buildings or elements or to the choice of individual components or materials. The implementation process is divided into the following stages:

(i) Establishing the life cycle: The determined life cycle applicable to all options is established in consultation with the investor in order to ensure that the time scale is compatible with investment objectives. Within the established overall life cycle study period, differing life cycles appear for the various components and elements constituting the asset.

(ii) Determination of available alternatives: To ensure that the best options are selected, all suitable alternatives relating to design solutions and materials and forms of construction are identified.

(iii) Estimation of total costs applicable to the available alternatives: The estimated current value cash flow for the determined life cycle applicable to each element or component includes capital costs, running costs, maintenance costs, repair and replacement costs, alteration costs, finance charges and residual costs or revenues. The total cost commitment for the overall life cycle comprises the sum of the life cycle costs of the individual elements and components.

(iv) Time-phasing costs to date of occurrence: Because estimated prices represent present day costs they are time-phased to the anticipated dates on which they are expected to occur. The time-phasing process incorporates price changes caused by inflation, changed working conditions, etc.

(v) Selection of discount rate: The selection of an appropriate or interest rate to convert the time-phased costs to future or present value equivalents, enables alternatives to be compared on an equitable basis at a common point in time.

(vi) Adjustments for income tax charges and depreciation allowances: The financial implications of income tax charges affecting both the discount rate and cash flow are computed. The financial relief precipitated by depreciation allowances is reflected as a reduction in life cycle costs.

(vii) Sensitivity analyses: This issue refers to testing the sensitivity of the analyses to the effects of changes to interest rates, life cycles or estimated costs.

Computation procedures

Three traditional methods employed in LCC studies are illustrated. All provide for cash flows, regardless of when they are incurred, to be converted to equal terms at common points in time. The methods are:

(i) Equivalent Present Value Method: Alternatives are evaluated in terms of their total single payment present worth.

(ii) Equivalent Annual Value Method: Alternatives are evaluated in terms of their equivalent annual value costs.

(iii) Equivalent Future Value Method: Alternatives are evaluated in terms of their total single payment future worth.

These methods, which are fully interchangeable, represent alternative means of presenting precisely the same information in a standard format.

Cost data reflecting current values are time-phased to represent actual costs as at the date of commitment. The prediction of future recurring or replacement costs must account for increases due to the following:

(i) Inflation.

(ii) Differences in working conditions and scale of operations. Replacement will not necessarily be on the same scale as the original operation and may be executed under more trying or difficult circumstances.

(iii) Costs of demolishing and removing existing work as well as the protection of remaining structures and finishings while the work is in progress.

(iv) Costs of disturbances to and/or by the occupiers during building operations.

Notwithstanding cost considerations representing the primary basis for comparative purposes, all options must be capable of fulfilling stipulated functional objectives. Apart from meeting acceptable technical standards and cost-effective qualities, a further criterion affecting the decision is the irreducible factor. An irreducible factor is one that has no alternatives and, as such, outweighs any cost considerations.

In the application of LCC analyses a number of issues are relevant to its successful implementation. These include income tax implications, tax depreciation allowances, the impact of inflation and financing considerations. These issues are individually examined in terms of their impact on LCC studies.

INCOME TAX IMPLICATIONS

General

The financial implications of income tax charges and tax depreciation allowances are investigated only insofar as they directly affect LCC studies. Whilst LCC is concerned primarily with costs, certain expenditures do cultivate tax implications with respect to income benefits. Therefore, apart from examining the effects of income tax on expenses, the indirect impact of tax on revenue is clarified.

Three tax issues are identified. These are the:

(i) Effects of income tax on the interest rate;
(ii) Indirect tax effects on revenue that results from expenditure commitments; and
(iii) Financial implications of tax depreciation allowances.

The effects of income tax on the interest rate

Income tax charges are equivalent to reductions in interest rates employed to transpose time-phased costs to present or future value sums. These adjustments to the applied interest rate result in delivering smaller future value sums and larger present value sums.

The indirect tax effects on revenue

When expenditure is classified as deductible for tax purposes, it realises a saving in income tax payable. Because LCC studies reflect only expenses, the financial relief created by tax permissible expenditures is treated as a reduction in life cycle costs. The value of the tax charge reduction, which is equivalent to a decrease in expenses, is dependent upon the payment amount and the applied tax rate. In the example illustrated in table 1 the R2 000.00 expense is equivalent to an after-tax charge of R1 200.00. In mathematical terms the tax relief value precipitated by permissible expenditure is the 'payment amount x [1 - t]' and the actual worth of a R2 000.00 cost commitment (assuming 40% income tax) would read:

$$\begin{aligned} \text{After-tax cost} &= A\,[1 - t] \\ &= 2\,000.00\,[1 - .40] \\ &= R1\,200.00 \end{aligned}$$

When expenditure represents a capital cost, it is not permitted as a deduction for tax purposes. Such charges derive no tax relief benefit and the full costs are included in the LCC analysis.

Table 1 Tax implications of expenditure of a revenue nature

	Project A	ProjectB
Gross annual income	R10 000.00	R10 000.00
Annual operating expence	3 000.00	3 000.00
Redecoration	0.00	2 000.00
Net income before tax	7 000.00	5 000.00
Income tax - 40	2 800.00	2 000.00
Net income after tax	R4 200.00	R 3 000.00

After-tax income difference occasioned by cost of redecoration = R1 200.00

In computing the present or future value equivalents for non-tax-deductible expenditure, effective after-tax interest rates are used in the equations to transpose data to their ultimate destination. If charges are designated as deductible for tax purposes, the benefits derived from the tax relief permutations are accommodated by multiplying the relevant equations by [1 - t].

The implications of tax depreciation allowances

Annual depreciation allowances represent positive cash flows and are processed as revenue streams that reduce life cycle costs. Because depreciation amounts are not cash outlays, but bookkeeping expenses that reduce taxable income, the method of accounting for the tax implications on these allowances differs from the procedure adopted in accommodating tax relief values attributed to operating costs. The primary distinction relates to the tax relief equation.

Tax depreciation allowances reduce the amount of tax payable and increase the after-tax income from an investment. In order to give a proper account for the financial implications of depreciation amounts, they are offset against the costs of the depreciated asset. For instance, the example in table 2 illustrates that the R3 000.00 depreciation allotment creates a R1 200.00 increase in after-tax cash flow, and effectively represents a reduction of R1 200.00 in the cost of the asset. In mathematical terms the depreciation amount is offset against the cost of the asset by the equation 'Depreciation amount x t' and accordingly R3 000.00 x 't' = R1 200.00.

Table 2 Tax depreciation allowances

	Project A	Project B
Gross annual income	R10 000.00	R10 000.00
Annual operating expenses	3 000.00	3 000.00
Tax depreciation allowance	0.00	3 000.00
Taxable income	7 000.00	6 000.00
Income tax - 40%	12 800.00	1 600.00
Net income after tax	R4 200.00	R5 400.00

After-tax income difference occasioned by tax depreciation allowances = R1 200.00

FINANCING COSTS

General

Although the subject of financing capital purchases is ignored by most of the literature pertaining to LCC studies, the issue remains a crucial factor in capital investment decisions. The logic supporting the contention that financing provisions are intrinsic components of the evaluation process is not unanimously accepted. For instance, Langston[18] maintains that borrowed money considerations should be excluded from LCC computations. This viewpoint is not reflected by Flanagan et al[19]. They argue that if the cost is financed through borrowing, explicit account needs to be taken of the resultant interest payments.

Borrowed money interest charges are tax deductible expenses that decrease taxable income and result in lower income tax payments. In contrast, loan capital repayments do not qualify as deductions for tax purposes and the total value of such amounts is reflected as an expense in the cash flow profile. In terms of LCC analyses, the computation complexities associated with interest and redemption repayments are largely dependent upon the financing arrangements. Two primary financing methods are pertinent. The first method provides for interest-only payments for the life of the loan and capital redemption at the conclusion of the loan period. The second procedure assumes a constant payment pattern in which interest and redemption amounts vary in value as the repayment cycle progresses. The method provides for the systematic reduction of borrowed capital to zero value at the conclusion of the loan term.

Interest-only mortgage loans

In terms of financial accountability, the interest-only type loan represents the less complex system. Interest charges are reflected as a series of tax deductible uniform payments. When loan repayment schedules do not correspond with the project life, the computed values are transposed to dates that match either the start or end of the determined overall life cycle.

Although the debt capital repayment amount at the end of the loan period reduces the after-tax cash flow, it does not constitute a tax deductible expense, and the tax relief factor is not applicable. If the capital repayment date and life cycle evaluation point do not correspond, the outstanding debt amount is converted to the appropriate present or future value position.

Amortising mortgage loans

Because typical mortgage type loans reflect uniform payment amounts comprising varying proportions of interest and capital redemption payments, they are more difficult to accommodate in LCC analyses. In a constant value redemption instalment schedule, interest charges initially constitute the major portion of each payment. Over time the interest apportionment is gradually reduced until a stage is reached when the position is reversed and the capital redemption portion establishes the dominant component. Because of lack of uniformity with respect to interest and redemption elements, uniform payment amortising type loans are best accounted for by developing separate cash flow schedules for the two components. Each payment amount is individually transposed to present or future value equivalents by employing the after-tax single payment amount formula.

While borrowing decreases immediate equity capital needs and postpones capital injection to the future, it does incur additional expenses in the form of interest charges. A problem associated with incorporating financing costs into LCC studies relates to the prospect of double accounting. Because all discounted cash flow techniques implicitly account for the repayment of capital, care must be taken to ensure that capital cash flows are not included more than once.

Table 3 Borrowing and cash flow profiles

Year	0	1	2	3
Cash inflow	Rx[1]	0	0	0
Cash outflow	Rx[2]	Ry[3]	Ry	Ry
Net cash outflow	0	Ry	Ry	Ry

Rx[1] = Amount borrowed from lender
Rx[2] = Amount paid for asset (in this instance equals borrowing)
Ry[3] = Interest and redemption payments to lender

A typical cash flow profile initiated by loan capital repayments is highlighted in table 3. An asset, purchased entirely by loan monies to the value of Rx, is repaid over a period of three years. Because the initial cash inflow is balanced by the initial cash outflow, the LCC cost commitment schedule conforms to the pattern of 'nil' payments in year zero followed by uniform payments for years one to three inclusive.

INFLATION AND LCC STUDIES

General

The estimated cash flow amounts in an LCC study reflect current prices which are time-phased to their anticipated payment dates. Either constant rand or actual rand values are adopted as the medium for reflecting price changes caused by inflationary pressures. Although Flanagan et al.[20] indicate a preference for accommodating the influence of inflation through the use of inflation-free interest rates, whereby cash flows are expressed in real or constant rand terms, the approach is not favoured in this paper. The actual rand methodology is preferred primarily because it obviates the complications created by projects displaying a mixture of inflation resistant and inflation dominated cash flows.

In the recommended approach current prices are time-phased to their anticipated payment dates. The projected payment amounts are then converted to equivalent present or future worths at after-tax interest rates.

FURTHER LCC ISSUES

General

While many authors endorse the concept of life cycle costing there are those who remain suspicious of its value as a cost appraisal measure. Although some of the criticisms are well founded, others originate primarily as a result of the failure to appreciate fully the concept of LCC. The more relevant problems and benefits associated with LCC studies are examined in the following paragraphs.

Understanding the interaction between capital and running costs

Misunderstanding of the interaction between capital and running costs frequently promotes unfounded criticisms of the LCC technique. For instance, the belief that lower running costs are necessarily the product of increased capital expenditure results is a common misconception. Larger capital budgets will not ensure that lower future maintenance and operating costs result. Many poor design decisions generate increases in both initial cost commitments and future running expenses. If a true interpretation of the relationship between initial capital costs and future running expenditure is to be ascertained, alternative options must be defined and compared on an equivalent basis.

The issue similarly promotes problems with regard to the acquisition of sufficient capital to implement the most economic proposal. When inadequate funds are allocated to a particular project it is often difficult to convince clients of the long-term advantages that can result from increasing capital budgets.

Investor objectives

One of the advantages of LCC is that it forces users to define investment objectives and to make implicit design decisions more explicit. The implementation of a systematic analytical procedure has the effect of separating subjective and objective considerations and of simplifying the evaluation of alternative design solutions. Notwithstanding these benefits, failure to identify investor objectives properly, frequently promotes negative attitudes towards the LCC concept as a result of conflict between management intentions and evaluation criteria. According to Stone[21] short-term developers are concerned with future costs only insofar as they anticipate the purchaser will take note of them. Whereas purchasers are intimately concerned with maintenance charges, the developer/seller is primarily concerned with the difference between building costs and selling price. If the distinctive forces that motivate individual investors are not clearly recognised, the LCC study will not necessarily be compatible with investor requirements.

Uncertainty in forecasting

Because the application of LCC in the construction industry is associated with the evaluation of long-term durable assets, forecasting is fundamental to its existence. LCC study assumptions include forecasts of future inflation rates, discount rates, lives of buildings and their component parts, income tax rates, and residual or salvage values. These assumptions are not unique to LCC analyses and extend to other capital investment evaluation procedures.

Forecasting introduces the problem of uncertainty which materialises irrespective of whether predictions are concerned with estimates of initial costs or forecasts of future running costs. The degree of uncertainty is dependent upon the reliability of available information and the time over which forecasts have to be made. For instance, although a reasonable degree of accuracy may be accomplished in estimating initial costs, difficulties may arise in accurately forecasting the future replacement costs of the same components because of uncertainty as to the extent of the disturbance factor in the alteration operations. In this regard the importance of sound professional judgement should not be underrated.

While it is acknowledged that there is always a measure of uncertainty as to the accuracy of predictions, modern risk analysis techniques have provided limited relief to the problem. Furthermore, predictions and assumptions are not unique to LCC studies. These deficiencies extend to all dynamic investment evaluation procedures that assess projects on the basis of their investment lives. It is argued that there are distinct benefits to be derived from the technique. Because it demands rational predictions, implicit assumptions are made explicit and objectively quantified. If no consideration is given to predicting future conditions it is comparable with the unrealistic presumption that current circumstances will proceed unchanged into the future.

Changes in interest rates

One of the main problems of LCC relates to the accuracy in forecasting changes in interest rates. Market-related interest rates employed in LCC analyses comprise interest and inflation components. Although the values attributed to these interest rates are dictated to a large extent by inflation pressures, because they frequently fluctuate in sympathy with inflation, movements in real interest rates tend to remain stable. The financial implications of interest rate changes are therefore not always as substantial as market movements indicate.

Obsolescence and durability

A number of factors are relevant to predictions in expected life cycles and these vary for different clients, buildings and their component parts. The economically productive time scale for a building is not necessarily the same as its probable physical life. Because it is possible to influence physical life to a certain extent by exercising care in component specification and material selection, or by implementing positive maintenance programmes, this cost may be quantified in economic terms. However, the ability to predict realistically costs associated with functional or economic obsolescence is questionable. Depending upon the extent of depreciation, obsolescence rectification ranges from minor works or renovation through to modernisation or complete redesign and construction programmes.
Although theoretically such charges can be related to failure of similar buildings, the unique nature of individual developments invariably ensures that the information is of limited value.

Assessment of income, indirect and intangible costs

LCC is an economic appraisal process capable of reaching conclusions based on cost considerations alone. Because their effects on total costs are difficult to measure, not all cost consequences can be costed directly. For example, an increase in initial costs introduced to enhance the appearance of a building may in the long term result in a higher occupancy rate, or greater contentment of the inhabitants. Costs and returns of this nature are difficult to measure in monetary terms alone. In addition, there are aspects such as prestige that are impossible to quantify and as such do not form part of the LCC study. These issues are addressed by Flanagan, Norman and Robinson[22]. They have developed an LCC framework that permits the value of intangible benefits and costs to be quantified and subtracted from the total costs of each option in order to identify the least cost alternative.

A further problem area is the exclusion of the effects of design decisions on revenue cash flow projections. Although revenue fluctuations may be measured in terms of reducing costs as a result of design modifications, the exclusion of any form of investment desirability evaluation from LCC studies does represent a distinct limitation of the technique.

Cost data

A major problem in South Africa is the virtual absence of suitable reliable cost data in the right form and detail to undertake studies of the nature envisaged. If LCC is to be introduced on a national scale, concerted efforts will have to be made for the collection of relevant cost information on an ongoing basis. The United States is probably the leader in the field of obtaining data in a suitable form for use in LCC analyses. Although restricted availability of appropriate information has been experienced in the United Kingdom, according to Flanagan et al.[23] the data problem is becoming less severe with many clients and consultant organisations building up extensive and well-designed data bases.

CONCLUSION

The technique of LCC embodies well-founded economic concepts whereby the cost implications of design decisions are analysed. The greatest strength and appeal of the approach is undoubtedly its suitability as a cost control measure that facilitates the financial comparison of design options. Whereas most other cost estimating procedures restrict the assessments to initial costs alone, the technique of LCC accommodates the long-term view with respect to the total cost of building ownership by establishing a mechanism whereby the relationships between initial and operating costs are effectively analysed.

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