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Life cycle costing—theory, information acquisition and application

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Especially in the last two decades of an increasingly-competitive business environment, dwindling resources and an ever-increasing need to obtain value for money in all areas of corporate activity, it has become essential that all available resources be used optimally (Griffith, J. W. and Keely, B. J., *Cost Engineering*, 1978, September/October, 165–168). Physical assets form the basic infrastructure of all businesses and their effective management is essential to overall success. It has thus become essential to plan and monitor assets throughout their entire life cycle, from the development/procurement stage through to eventual disposal. Life cycle costing* is concerned with optimising value for money in the ownership of physical assets by taking into consideration all the cost factors relating to the asset during its operational life. Optimising the trade-off between those cost factors will give the minimum life cycle cost of the asset. This process involves estimation of costs on a whole life basis before making a choice to purchase an asset from the various alternatives available. Life cycle cost of an asset can, very often, be many times the initial purchase or investment cost (Hart, J. M. S., *Tetrotechnology Handbook*, p. 22, HMSO, London, 1978; Hysom, J. L., *Journal of Property Management*, 1979, 44, 332–337). It is important that management should realise the source and magnitude of lifetime costs so that effective action can subsequently be taken to control them. This approach to decision making encourages a long-term outlook to the investment decision-making process rather than attempting to save money in the short term by buying assets simply with lower initial acquisition cost. It is suggested project managers should familiarise themselves with what the approach involves, to better appreciate how they might then contribute to the enhanced quality decision making which it makes possible. © 1997 Elsevier Science Ltd and IPMA

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The nature of life cycle costing

There is considerable evidence to suggest that many organisations, in both the private and public sectors, make acquisitions of capital items simply on the basis of initial purchase cost. With the notable exception of military applications,[5,6] very few assets seem to be appraised on the basis of their total lifetime costs. Two decades ago it was claimed that, "Very few firms appear to undertake life cycle costing studies at the acquisition stage of a physical asset's life, nor do they collect all costs over their life cycles",[7,p.v] and apart from isolated examples,[8,9] the evidence suggests this situation has not radically changed. Perhaps the two major exceptions to the general rule, apart from the previously-cited military one, lie in the increasing body of evidence citing the application of life cycle costing (LCC) concepts to buildings (construction and use), evident through the work of such as Alexander,[10] Anderson,[11] Rich,[12] Fullman,[13] Bird,[14] Wübbenhorst[15] and Ashworth[16]; and the adoption of the technique in public sector applications.[17,18]

In addition, national surveys have indicated that the preparation of cash flow projections at the acquisition stage, and subsequently discounting the figures back to the present using discounted cash flow techniques, are by no means universally applied. As Argenti[19, p 78] has claimed, "some managers do not know what cash flow is; one can hardly expect them to be able to discount it."

Several definitions of LCC exist. As useful as any, and shorter than most, is:

*The concept is not new, and was actively promoted in the UK by the Department of Industry through its Committee for Terotechnology in the mid- to late-1970s. See Sherif, Y. S. and Kolarik, W. J., *Omega*, 1981, **9**, 287–296 for a brief history of the concept.

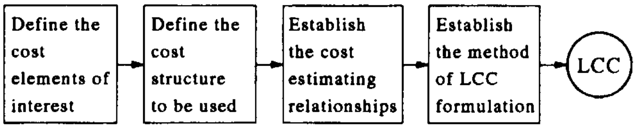

Figure 1 Harvey's life cycle costing procedure

> "The life cycle cost of an item is the sum of all funds expended in support of the item from its conception and fabrication through its operation to the end of its useful life"[20, p 39]

Thus, the LCC of a physical asset begins when its acquisition is first considered, and ends when it is finally taken out of service for disposal or redeployment (when a new LCC begins).

LCC seeks to optimise the cost of acquiring, owning and operating physical assets over their useful lives by attempting to identify and quantify all the significant costs involved in that life, using the present value technique. LCC is concerned with quantifying different options so as to ensure the adoption of the optimum asset configuration. It enables total LCC, and the trade-off between cost elements during the asset life phases, to be studied to ensure optimum selection.[21]

LCC procedures

In an article which comprehensively reviewed the LCC technique, Harvey[22] proposed the general procedure for LCC analysis summarised in *Figure 1.*

In Figure 1:

- **The cost elements of interest** are all the cash flows that occur during the life of the asset. From the definition of LCC previously provided it will be apparent that the LCC of an asset includes all expenditure incurred in respect of it, from acquisition until disposal at the end of its life. Whilst there is general agreement that *all* costs should be included, opinion varies as to their precise identification.
- **Defining the cost structure** involves grouping costs so as to identify potential trade-offs, thereby to achieve optimum LCC. The nature of the cost structure defined will depend on the required depth and breadth of the LCC study, and a number of alternative structures have been proposed. Thus White and Ostwald[20] divided costs into the three categories of: engineering and development; production and implementation; and operation. *Figure 2* illustrates the three stages.

Whilst also developing a model based on three categories, those selected by Callick[23, p 2] were designated the costs of use, ownership and administration, whilst Jeffery[24] proposed a categorisation comprising engineering, manufacturing, distribution, service costs, sales costs and refurbishment.

In spite of these different cost categorisations, in the end the detailed costs of each component will depend upon the particular project, system or product under consideration. According to Harvey[22, p. 344], "The important point is that the structure must be designed so that the analyst can perform the necessary LCC analysis and 'trade-offs' to suit the objectives of the project and the company concerned."

- **A cost estimating relationship** is a mathematical expression that describes, for estimating purposes, the cost of an item or activity as a function of one or more independent variables. Historically-collected costs will normally be the basis of such estimates, utilising linear, parabolic, hyperbolic, etc., relationships.
- **Establishing the method of LCC formulation** involves choosing an appropriate methodology to evaluate the asset's LCC. One that has stood the test of time is that proposed by Kaufman.[25]

Kaufman has provided one of the most original contributions ever to the body of LCC knowledge, whereby he developed a formulation based on the eight-step approach indicated below and shown in *Figure 3.*

- establish the operating profile;
- establish the utilisation factors;
- identify all the cost elements;

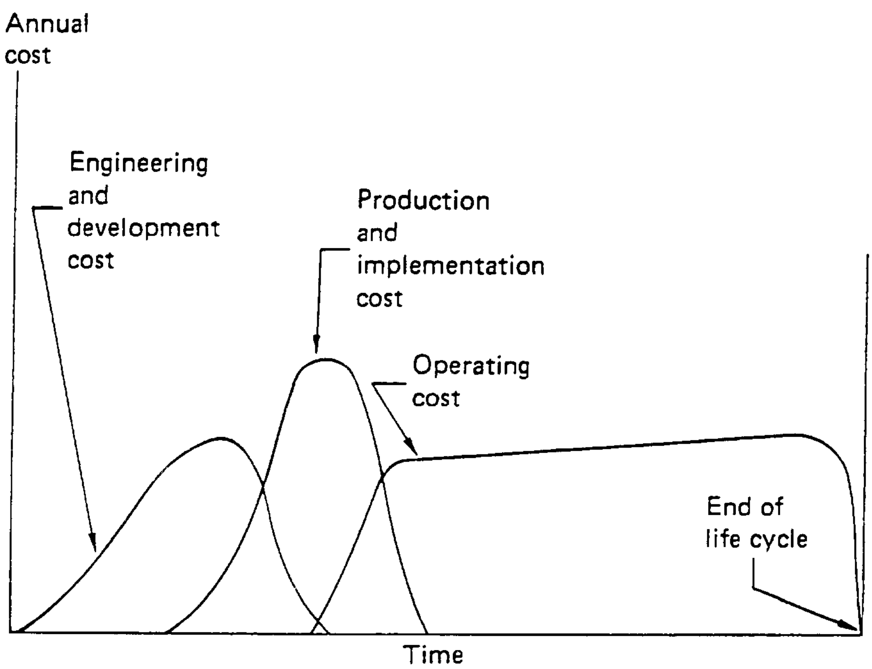

Figure 2 One example of cost categorisation (stages of life cycle costs)

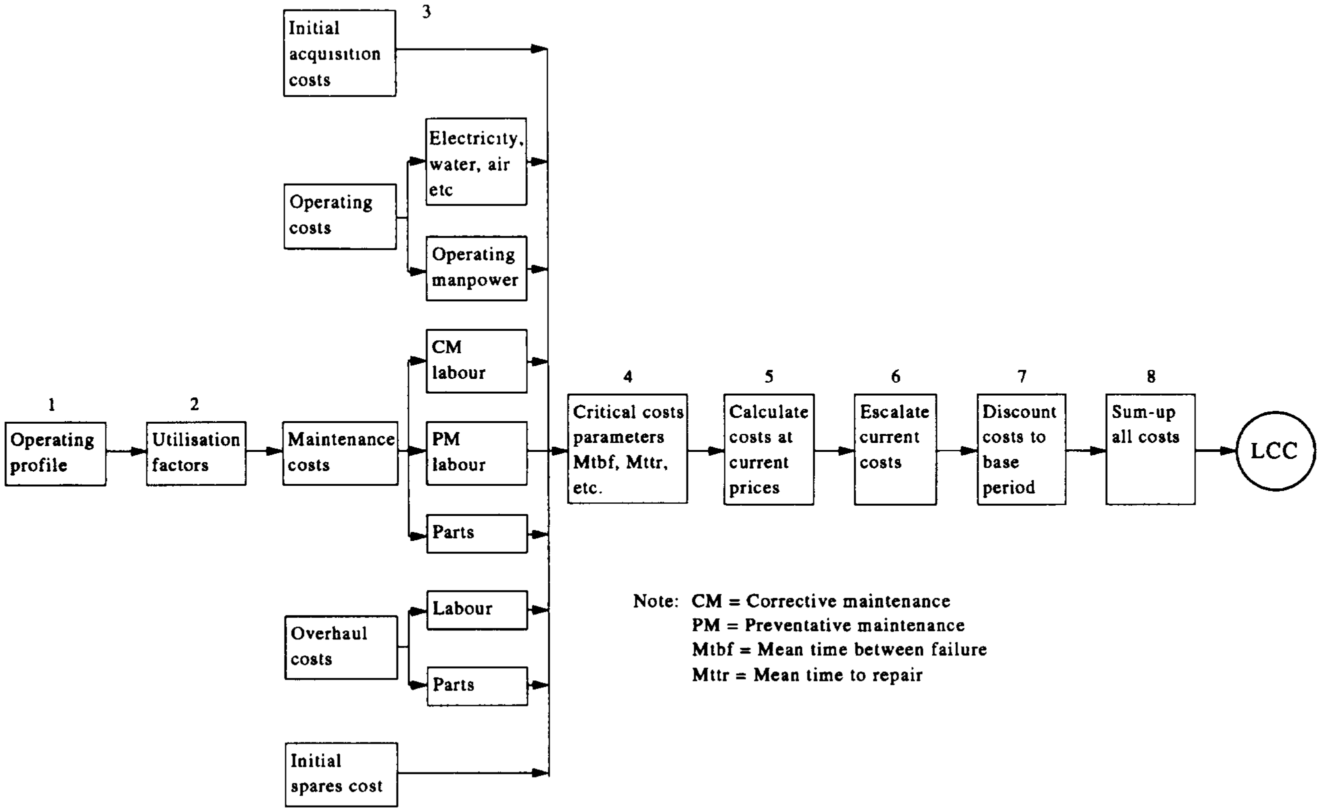

Figure 3 Kaufman's life cycle costing formulation

- determine the critical cost parameters;
- calculate all costs at current prices;
- escalate current costs at assumed inflation rates;
- discount all costs to the base period;
- sum discounted costs to establish the net present value.

Step 1: The operating profile (OP) describes the periodic cycle through which the equipment will go, and indicates when equipment will, or alternatively will not, be working. It comprises the modes of start up, operating and shut down.
Step 2: Whilst the OP tells us the proportion of time the equipment will be operating or not operating, the utilisation factors indicate in what way equipment will be functioning within each mode of the OP. Thus, even within the 'operating' mode, a machine might not be working continuously.
Step 3: Every cost element or area of cost must be identified.
Step 4: The critical cost parameters are those factors which control the degree of the costs incurred during the life of the equipment. Stevens[26] has suggested the most significant of these are:

- time period between failures (Kaufman's 'MTBF');*
- time period between overhauls;
- time period of repairs (Kaufman's 'MTTR');*
- time period for scheduled maintenance;
- energy use rate.

Step 5: All costs are first calculated at current rates.
Step 6: All costs (despite the fact that Kaufman only mentioned labour and material) need to be projected forward at appropriate (that is, differential) rates of inflation.[28] The difficulty in projecting such figures should not be underestimated, since lack of precision here can lead to inaccuracy in the final calculations. However, inflation rates, like interest rates, have something of the 'self-fulfilling prophesy' to them, and if forecasts from 'experts' are available, then some reliability may be placed upon them.†
Step 7: It should be recognised that money has a time value and the cash flows occurring in different time periods should be discounted back to the base period to ensure comparability. How to establish the appropriate discount rate is, of course, the subject of much discussion!
Step 8: Summing all the cash flows involved will enable the LCC of the asset to be established. Comparisons between competing assets can then be undertaken, and the fallacy of opting simply for the asset with lowest capital cost will then be exposed — the more expensive asset often has a lower total LCC.

Elements of life cycle costing

Background

The objectives of LCC identified by the Royal Institute of Chartered Surveyors[30] are:

- to enable investment options to be more effectively evaluated;
- to consider the impact of all costs rather than only initial capital costs;
- to assist in the effective management of completed buildings and projects;
- to facilitate choice between competing alternative.

The LCC approach identifies all future costs and benefits and reduces them to their present value by the use of the discounting techniques through which the economic worth

*See Fricker[27] for a development of these concepts.
†An alternative approach is then to ignore inflation completely, and when applying Step 7, discount at the *real* rate of interest, rather than a *money* rate, which, following Fisher,[29] may be defined as $r_{money}=(1+r_{real})(1+i)-1$, where r is the rate of interest and i is the rate of inflation.

of a project or series of project options can be assessed. In order to achieve these objectives the following elements of LCC have been identified:

- initial capital costs;
- life of the asset;
- the discount rate;
- operating and maintenance costs;
- disposal cost;
- information and feedback;
- uncertainty and sensitivity analysis.

Initial capital costs

The initial capital costs can be divided into three sub-categories of cost, namely:

- purchase costs;
- acquisition/finance costs;
- installation/commissioning/training costs.

Purchase costs will include assessment of items such as land, buildings, fees, furniture and equipment. They can be estimated by obtaining quotations from suppliers and agents. Finance costs include the cost effect of alternative sources of funds and gearing.[31] The other costs include the costs of installing the machine and the costs of training workers to operate it.

In a nutshell, the capital cost category includes all the costs of buying the physical asset and bringing it into operation.

Life of the asset

The forecast life of an asset is a major influence on life cycle analysis in view of the exponential nature of the effect of this variable. There are five possible determinants of an asset's life expectancy:[32, p 29]

Functional life — the period over which the need for the asset is anticipated;
Physical life — the period over which the asset may be expected to last physically, to when replacement or major rehabilitation is physically required;
Technological life — the period until technical obsolescence dictates replacement due to the development of a technologically superior alternative;
Economic life —the period until economic obsolescence dictates replacement with a lower cost alternative;
Social and legal life — the period until human desire or legal requirement dictates replacement.

Stone[33, p. 52] drew attention to the importance of the influence of the forecast life of an asset in life cycle analysis because:

> "Errors of five or ten years in the predicted life will not make very much difference to the predicted equivalent costs when the life is fifty to sixty years. The errors in predicted costs, and hence design decisions, are likely to be greater when the life of the asset is taken substantially shorter than conditions warrant than when ... longer than justified."

The discount rate

As the life cycle costs are discounted to their present value, selection of a suitable discount rate is a crucial decision in a LCC analysis.[34] A high discount rate will tend to favour options with low capital cost, short life and high recurring cost, whilst a low discount rate will have the opposite effect. The discount rate may reflect the effect of only the real earning power of money invested over time or it may also reflect the effects of inflation.

Much of the literature in this area offers little in the way of firm recommendations regarding the final selection of an appropriate rate — estimates vary between 3–4% and in excess of 20%. Further, there is a variety of views within the general discourse regarding the actual composition of the discount rate. The most popular methodologies appear to be:

- at the current or expected rate the organisation must pay for the use of its borrowed funds;
- at the rate of return that could be expected from the loaning of money, but which is denied to the organisation by the need to fund its own projects (sometimes referred to as the opportunity cost);
- at the lowest rate of industrial borrowing for a financially sound, well-established company;
- a test discount rate can be used based on the assumption that when inflation rates are reasonably low there is a stable relationship between inflation and base rate, implying a real discount rate of 4%;
- investments in long-term treasury bonds can be assumed to have no risk. Therefore, the discount rate can be taken as the Treasury bond rate less an allowance for the expected rate of inflation.

The appropriate discount rate will vary significantly from organisation to organisation and will need to be determined by the skill of the industrial accountant rather than by mere arbitrary selection. As in the case of estimating the appropriate rate of inflation, calculating the relevant discount rate is rarely easy. However, help is available from the financial management sub-discipline of accounting, where over the years many sophisticated techniques have been developed to assist with this particular problem.

Operating and maintenance costs

LCC is all about operating physical assets to minimum cost. Accordingly, estimation of operating and maintenance costs is essential to minimise the total LCC of the asset. The operating costs of an asset would include direct labour, direct materials, direct expenses, indirect labour, indirect materials and establishment costs. The estimation of these costs is based on both predicted and actual experience of the performance of similar assets.[35] In most organisations estimates regarding productive assets are made by the engineering department.

Maintenance costs include direct labour, materials, fuel power, equipment and purchased services. Maintenance costs can normally be broken down into smaller classifications such as:

- regular planned maintenance;
- unplanned maintenance (responding to faults);
- intermittent maintenance (for major life refurbishment).

A regular, planned, preventive maintenance policy reduces the downtime costs but resources are used in the form of maintenance expenditure. The 'run it until it breaks' approach, on the other hand, reduces the maintenance expenditures but increases the downtime loss. This inverse relationship is illustrated in *Figure 4*.[36]

It is essential that a regular, planned maintenance policy is maintained for those items of equipment that incur high

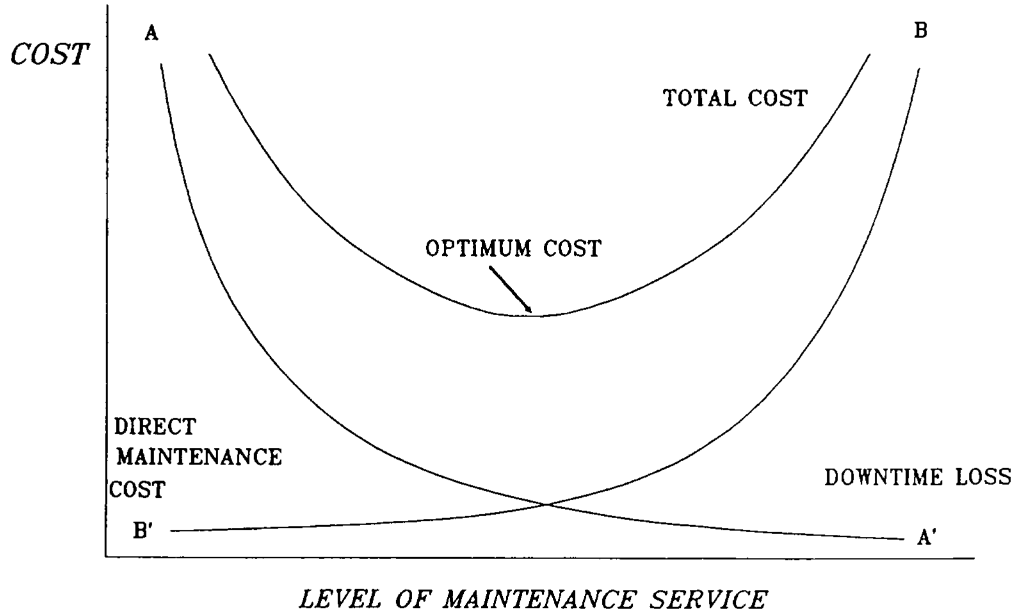

Figure 4 The maintenance–cost relationship

downtime costs whereas items of equipment incurring low downtime costs can be attended to or replaced as they wear out. The key factor is to find an optimal level of maintenance service in order to be consistent with the organisation's objective of attaining minimum total cost.

Disposal cost

This is the cost incurred at the end of an asset's working life in disposing of the asset. The disposal cost would include the cost of demolition, scrapping or selling the asset, adjusted for any tax allowance or charge upon resale. Such costs would be deducted from the residual value of the asset at the end of its useful life.

Information and feedback

The efficacy of LCC as a technique is dependent upon the informational intelligence captured by the organisation. It has been commented:

> "The cost of collecting information and undertaking a life-cycle costing must be kept in proportion. The question which might be asked with effect is whether the information is only 'nice to know' or is really needed and can be used"[7, p 53]

A major part of the literature identifies information and feedback as a subject in its own right. Information capture, feedback, analysis and use within an organisation is multidisciplinary but with the major role being taken, necessarily, by the organisation's accountants since the majority of the information is expressed in monetary terms. The information sought by LCC will involve financial, time related, and quality data associated with the capital costs of acquisition, design/operational trade offs and consequential running costs of the asset.

Difficulties are more likely to be associated with obtaining and forecasting the operational and maintenance elements of the asset life cycle, identified[23] as:

- failure rate and downtime forecast;
- forecast spares requirements;
- maintenance requirements;
- annual maintenance cost forecast, for example, as a percentage of replacement costs.

Data, and hence information, also need to be collected during the asset life cycle to facilitate monitoring of the asset's performance in operation and provide a source of intelligence on which to base future decisions.

It is the data capture and information feedback system which closes the control loop and which, in practical terms, will be the governing factor in the success or failure of the LCC element — leading Knipe[37, p 51] to conclude:

> "Unless some provision is built into management control for continuous monitoring of various aspects — and with it some form of 'alarm' system, — it is only too easy for the individual to become complacent, accepting what is being done as the ultimate in control."

Uncertainty and sensitivity analysis

LCC is highly dependent on the assumptions and estimates made whilst collecting data. Even though it is possible to improve the quality of these estimates with the assistance of historical data and statistical methods, there is always an element of uncertainty associated with these estimates and assumptions.

Macedo *et al.*[38, pp. 299–300] identified the following five major sources of uncertainty:

- differences between the actual and expected performance of the system subsystems could affect future operation and maintenance costs;
- changes in operational assumptions arising from modifications in user activities;
- future technological advances that could provide lower cost alternatives and hence shorten the economic life of any of the proposed systems;
- changes in the price levels of a major resource such as energy or manpower, relative to other resources can affect future alteration costs;
- errors in estimating relationships, price rates for specific resources and the rate of inflation in overall costs from the time of estimation to the availability of the asset.

There is evidence[39] to suggest that sensitivity analysis will become more widely practised as a direct result of the development of computer software packages, which not only have the basic accountancy element of LCC but also the ability to perform a wide range of sensitivity studies, enabling them to embrace more accurately the dimension of qualitative assessment.

When undertaking a LCC analysis, there may be some key parameters about which uncertainty exists, usually because of the inadequacy of the input data. How sensitive are the results to variations in these uncertain parameters? Blanchard[40] suggested the following should be the subject of sensitivity analysis:

- frequency of the maintenance factor;
- variation of the asset's utilisation or operating time;
- extent of the system's self-diagnostic capability;
- variation of corrective maintenance hours per operating hour;
- product demand rate;
- product distribution time (the 'logistics pipeline');
- the discount rate.

The rate of inflation assumed in the analysis would be an obvious addition to this list, but generally every factor needs to be considered, a change in which is likely to have a significant impact on LCC.

Cost trade offs

The possibility of trading-off initial enhanced capital cost against subsequent revenue savings is one of the underlying principles of a LCC analysis. This aspect may be illustrated by reference to *Figure 5*.[7]

An increase in capital expenditure, as illustrated by Curve *A*, results in increased asset availability and reduced maintenance costs, measured by curve *B*. Where total cost, curve *C*, is at a minimum, the optimum LCC of asset ownership is derived. The lowest capital cost alternative can, in contrast, be seen to have a very high LCC. In many cases, the optimum LCC is not critical, such that different combinations of capital and maintenance cost levels between points *V* and *W* will not significantly affect LCC.

A budget constraint is also shown, with the thick arrows indicating constraint on capital and maintenance expenditure, and the thin arrows a life-cycle constraint for the asset LCC as a whole.

As regards specific examples of trade offs, the following may be considered:

- devote more resources to the R & D stage to increase reliability and maintainability and thereby reduce maintenance costs;
- increase machine efficiency (involving higher development/capital costs) to reduce scrap;
- spend more on automation (higher initial costs) leading to lower manning costs;
- buy a more expensive machine with a longer life.

Information requirements for LCC analyses

Introduction

It is usual to make appropriate entries in the asset register, once an asset has been installed, for the purposes of audit, stock control and calculation of depreciation. LCC necessitates the provision of additional information, and it may also be necessary to restructure existing data-collection systems in order to provide the data now required. Most organisations will already be providing forms giving much of the detail required, so all that might be necessary is a revision of the coding system applied to the documents which are an integral part of the existing paperwork system.

By ascribing additional codings, it should be possible to

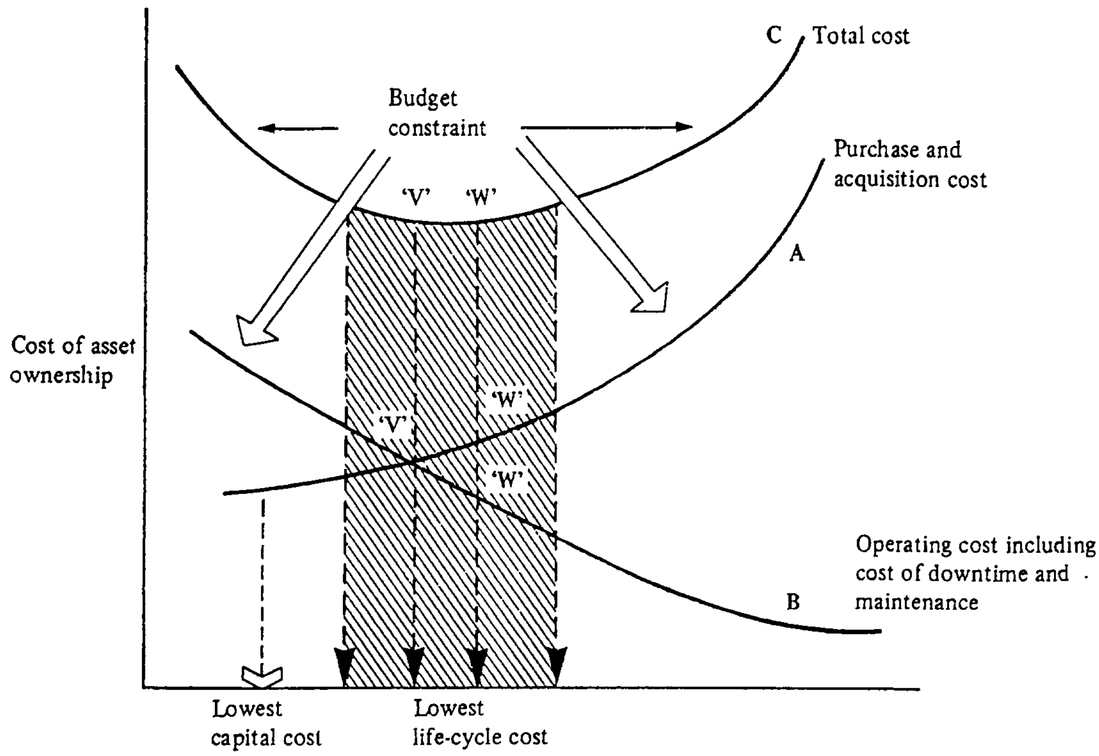

Figure 5 Cost trade-offs in asset ownership

identify the specific asset, or at least group of assets, incurring the particular cost being analysed. For LCC purposes it becomes necessary to distinguish between different types of expenditure, so maintenance and stores issue notes may be analysed so as to illustrate the cause or reason for work. Routine maintenance, scheduled overhauls, component failure, etc. all become legitimate categorisations.

The keeping of detailed asset registers cannot be overemphasised. Not only are they essential from the point of view of monitoring actual costs incurred against postulated LCC, but they are also invaluable in providing cost estimates for new equipment. This is because, despite perhaps significant changes in design, capacity, operator requirements and technology, few assets are entirely revolutionary. Past records of cost and performance can therefore be used to derive forecasts for newly-acquired assets, and to calculate trade-offs between the cost variables involved.

It therefore becomes imperative to keep accurate records of such aspects as:

- running hours;
- production hours;
- downtime and value of lost production;
- reasons for downtime;
- cause of any damage;
- maintenance time and cost;
- spares usage and cost.

Exactly what cost components should be included in the LCC exercise is not the subject of total agreement, and it is probably very valid that opinions should differ. However, the list that is developed must be adequate to identify the potential interaction and trade-off between the cost components. In the very process of defining the significance of these costs and cost-relationships, the accountant will be able to assist in determining the information output required, and justify the need for collecting and collating information to generate LCC information.

Since it is apparent that a LCC analysis can only be as good as the input data, considerable thought must go into the design of the requisite information system. The company's existing accounting systems will be important, but by no means the only, sources of data. In addition, access will be required to the complete technical and financial history of an asset's maintenance, and this will be provided by the prime documents used to record, control and allocate expenditure, and comprising such things as job cards, stores requisitions, invoices and petty cash vouchers.

Data sources

The data requirements to produce a LCC analysis are extensive, and will probably be an amalgam of information obtained both in-house (principally from the operation of similar machines), and of performance forecasts provided by the supplier or manufacturer. It is probably advisable to have a checklist of all aspects which potentially contribute to the cost-effectiveness of a particular capital asset,[41] and cost-effective trade-offs can then be performed amongst the parameters.

If all the required information is not available from the supplier or manufacturer, other sources may need to be investigated such as trade associations or other users of the same equipment.

What is essential is knowledge of reliability, capacity utilisation and maintenance procedures, leading to an understanding of the relationship between the capital costs of specification, design, acquisition and disposal, and the revenue costs of operation and maintenance.

These concepts are illustrated in *Figure 6*,[7, p. 15] which shows the relationship between capital and revenue costs, the potential trade-off between costs and engineering features, and the organisational functions of an enterprise.

Depending on the importance of physical assets to an enterprise and the cost of compiling LCC records, it may be worth developing an integrated LCC database. The items that might be incorporated are indicated in *Figure 7*.[42, p 15]

The absence of an appropriate data collection system means, according to Powley,[43, p. 141], "the decision is all too often influenced by a manual search of unsuitable records and recourse to the vagaries of human memory —

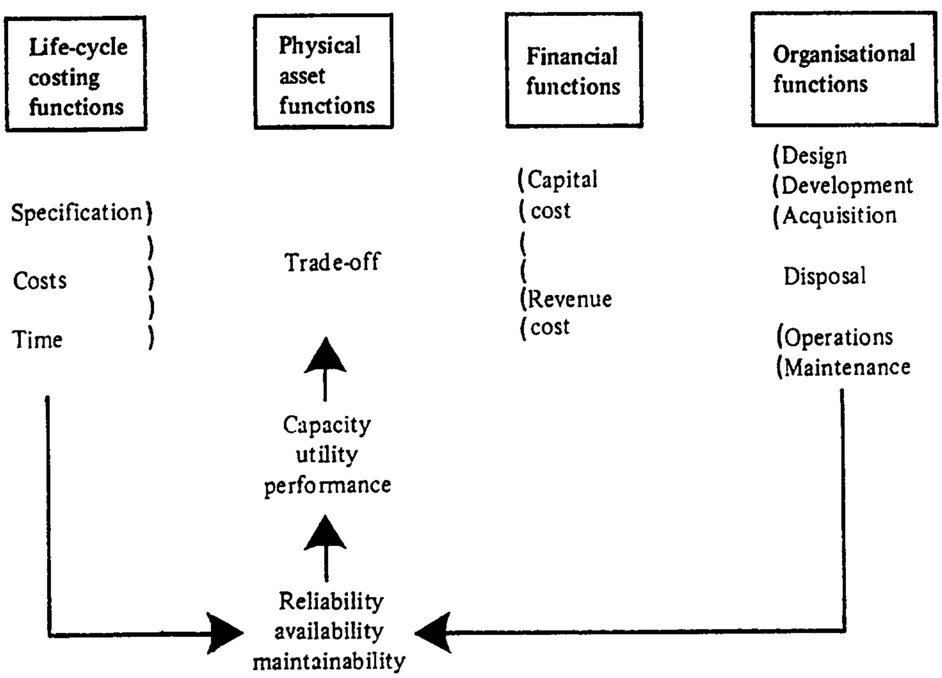

Figure 6 Key factors in life cycle costing

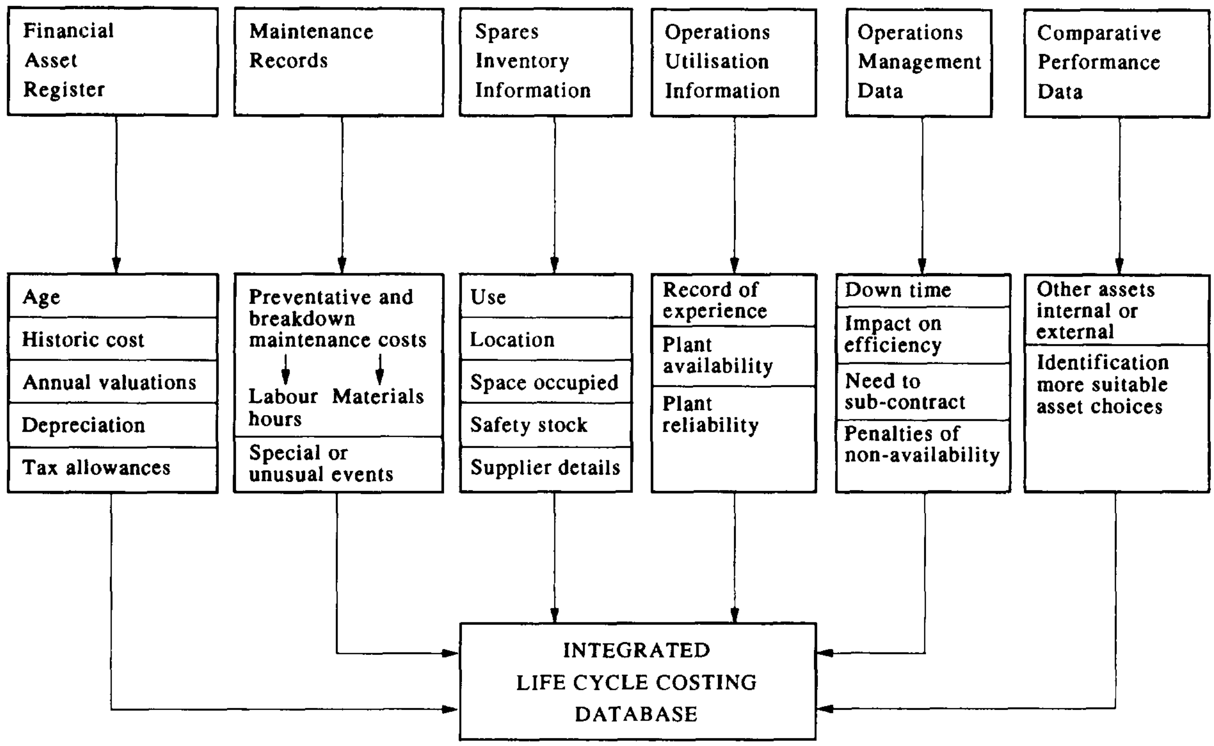

Figure 7 Design features for a life cycle costing database

notoriously unreliable if the person in question feels that the correct answer may reflect unfavourably on his abilities.''

In addition, the use of the database suggested earlier will be valuable in promoting improved management planning and control. The exercise will indicate where records are duplicated or could be simplified, and where information is lacking or inadequately recorded.

Forecasting life-cycle costing data

Whilst the maintenance of adequate records is a pre-requisite of a LCC exercise, clearly past records are only of use to the extent that they are useful in predicting the future.

Whilst forecasting is notoriously inexact, that should not dissuade those engaged in LCC from attempting it. In no way, in other words, is it ''time to abandon forecasting and to consign it with witchcraft and oracle consulting to the misguided foibles of a past era.''[44, p. 28]

Even if sufficient data is available in current terms for a LCC analysis, the problem still exists of how to project those figures into the future. What statistical methods are available to the accountant to help him/her forecast the future cash flows associated with ownership of a particular fixed asset? These essentially fall into the three categories identified of intuitive, casual and extrapolative.

For the effective application of LCC, it is not sufficient that a first-class information system be created. It is necessary in addition that feedback occur for the benefit of everyone both inside and outside the organisation. Concern should therefore not only be with collecting, validating, analysing and presenting factual data for LCC purposes, and in monitoring progress. Active engagement in the feedback process is also a pre-requisite.

Unless the information system set up in support of LCC is used as an integral and efficient part of the organisation, it will be impossible, or at the very least very onerous, to make correct decisions vital for capital investment programmes.

The essence of the LCC approach is to obtain, record and use data on current activities but for the benefit of future asset acquisition decisions. The feed-back of LCC experience to equipment manufacturers is, for example, of crucial importance. What better guide can there possibly be than user experience?

A case study — South Yorkshire Passenger Transport

This case study relates to South Yorkshire Passenger Transport Co. Ltd (SYPT) as the organisation existed in 1990 (aspects of confidentiality having prevented an earlier exposure of the information here presented).

SYPT's principle activity is the provision of passenger transport services by road. Its turnover in the year 1990 was £51,416,000 which included revenue from bus ticket sales, service tender receipts and proceeds from private hire. Its fixed assets were worth £28,885,000 out of which passenger vehicles accounted for about £11,775,000. The company purchases vehicles, which form a major part of the capital expenditure, on a regular basis and the decision to purchase them is based on the LCC technique.

In the mid-1970s LCC was introduced into the company as a result of the availability of sophisticated computer systems and increased information technology which enabled collection and analysis of information in a more comprehensive manner. Prior to this the information had been collected manually and the required level of detailed analysis was not possible. Additionally, support via Government grant (substantial at the time) ceased. This enhanced the need to minimise total LCC rather than merely minimising initial purchase cost.

In 1990 the company purchased 50 Volvo/Alexander single deck vehicles and 50 Mark III Dodge/Reeve Burgess midibuses. The company received a warranty of seven years from the manufacturers in respect of certain major components, such as the engines. From previous experience it was known that various bus sub-systems have different lifetimes. Thus the body would be expected to have a life span of about 12–15 years; the engine would need refurbishment after about 6–8 years; other parts might have a life cycle of about three years.

The operation costs of the buses consist mainly of two components: fuel expenditure and wear and tear on tyres. The company has a policy of running its buses on main routes at full capacity during their warranty period, and then putting them to side services once the warranty period has expired, new buses then taking their place. On average, a new bus runs about 60,000 miles per year during its warranty period. On this basis, the fuel expenditure over the years can be estimated. When new buses are bought, the tyres are immediately sold to a contractor who is then responsible for the replacement and maintenance of the tyres over the life of the bus. The contractor charges the company a fixed rate per tyre per mile the bus covers. Thus both fuel and tyre expense are variable costs, related to the mileage of the bus.

The company has a computer network which produces information regarding the hours spent on servicing buses each month. On average a new bus requires 12 h per month for maintenance, although the figure naturally increases as the bus ages. A 12–15 year old bus requires about 30–40 h of maintenance per month. After this age, increasing unreliability makes it difficult to estimate the number of maintenance hours required. The cost of maintenance per hour is multiplied by the number of hours estimated to calculate the maintenance cost over the life of a bus. There is no provision for downtime costs if the buses require unplanned maintenance in case of breakdown. Rather, the company's policy is to hold a stock of relief buses which take the place of those that break down. A 15% overhead is added to the 'normal' calculated cost when buses in this reserve pool are run. The breaking down of a bus thus has no (or only marginal) effect on turnover but the overheads incurred are deducted from the profit.

As previously mentioned, different components have different life expectancies, and the engine, for example, requires refurbishment at the end of 6–8 years. Once this has been incurred, there follows a fall in annual maintenance costs in subsequent years, and the engine will be expected to run smoothly for the next 3–5 years. This pattern has to be taken into account when estimating costs over the lifetime of a bus. Based on the features described, the annual estimate of operating costs will display a slow increase for the first (approximately) seven years to major refurbishment, then they rise sharply during the year of major expenditure, and then fall before gradually rising annually again. The costs peak at around the 10–12 year mark, and then more or less stabilise till the end of the life of the bus. There is no estimation of disposal costs as it is difficult to forecast these costs for 12–15 years in the future. Most buses are eventually sold at their scrap value and any adjustment made to profits in that year.

The estimated life cycle costs are discounted at an assumed monetary cost of capital of 15%, after including a standard inflation rate assumed over the life of the asset. If two alternatives have similar discounted costs, then a choice will be made by the Financial Director taking into account non-financial factors such as the credibility, reliability etc. of the suppliers.

The company uses the information generated for feedback purposes with the help of their computer network. It was thus found that the actual maintenance costs of the Volvo/Alexander buses for the first year turned out to be less than the costs estimated of the time of their acquisition. These actual costs were then incorporated into the making of revised future estimates when considering the purchase of similar buses. The cost estimates are also used to prepare cash flow statements and are set as targets for future years in order to control maintenance and operation costs.

No conflict between the finance department and engineering department was experienced whilst introducing and operating a LCC approach within the organisation. The engineering department makes estimates of the various costs involved and of the life period of the buses, and these figures are accepted by the finance department for the purposes of management control. No specific training of personnel was required to implement LCC.

SYPT also uses LCC for investment appraisal of its other assets such as land and buildings, although the application is mainly towards bus purchases, since these are acquired in bulk on a regular basis. Additionally, they have a comparatively shorter life period over which it is easier to estimate their life cycle costs. The company intends to continue using life cycle costing in the future as they consider it to be the most suitable investment appraisal technique.

Conclusion

LCC is a concept which aims to optimise the total costs of asset ownership, by identifying and quantifying all the significant net expenditures arising during the ownership of an asset. As Mott[45, p. 121] has maintained:

> 'Every year numerous purchases of buildings and equipment are based on the acquisition cost alone. Purchasing officers and other managers may be beguiled by a seemingly attractive acquisition cost for which "benefit" their firms will pay in later years through high running costs or a short life. Lowest purchase price does not necessarily minimise total cost over the whole life of the asset and therefore does not maximise profits.'

By examining trade-offs between the different cost areas, LCC attempts to ensure the optimum selection, use and replacement of physical assets. Its use throughout Britain, in all types of organisation, is to be actively encouraged.

LCC is concerned with optimising value for money in the ownership of physical assets, but its achievement depends upon the supply of accurate, relevant and speedy information. This flows from the operation of current assets, suppliers and other users of similar assets, and by application of appropriate statistical techniques to forecast future costs of ownership. Very careful thought must be devoted to the design of the management information system necessary to capture this wealth of information. This paper has provided some pointers to those interested in pursuing the LCC approach to asset acquisition.

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