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INTRODUCTION TO LIFE CYCLE COSTING

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Abstract

This introductory paper aims to make Life Cycle Costing (LCC) understandable and usable by average engineers. Procurement decisions for capital equipment must be based on the total life cycle cost rather than the usual practice of procurement based on the initial purchase price. In recent years, LCC has become a part of strategic cost management, and the concept can be applied to the effective procurement of engineering assets. LCC provides insights into the total cost of acquisition and ownership and thus effectively supports decision-making in the evaluation of various alternatives. The primary objective of this paper is to assist engineers in understanding the methods used in the development of models for estimating the life cycle cost of capital assets.

1.0 Introduction

The purchasing decision in the capital equipment business is continually challenged to use value for money as one of the important criteria necessary to meet the stringent demands of customers in a very competitive global market. The value-added engineering approach is a strategic thinking process that involves the systematic and objective assessment of equipment and component alternatives. In this approach, all alternatives are compared using life-cycle costing because the alternatives for each equipment are defined to satisfy the same basic function or set of functions. The life cycle cost refers to all costs associated with the product or system as applied to a defined life cycle. The life cycle of a product begins with the identification of the need and extends through design, production, operation, maintenance, support, and disposal. LCC identifies all future costs of the product phases and reduces them to their present value using discounting techniques through which the economic worth of a product or product options can be assessed. LCC is used to assist in decision-making, budget planning, cost control, and a range of other activities that occur over the life of complex technological equipment.

The objectives of LCC are (Flanagan and Norman, 1983):

- To enable investment options to be more effectively evaluated.
- Consider the impact of all costs rather than only the initial capital costs.
- To assist in the effective management of completed projects.

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- Facilitate choices between competing alternatives.

In order to achieve these objectives, the following cost elements have been identified (Woodward, 1997):

- Initial capital costs
- Life of asset
- Discount rate
- Operating and maintenance costs
- Disposal cost

1.1 Initial capital (Acquisition) costs

The initial capital (Acquisition) costs can be divided into three sub-categories of cost:
(1) purchase costs
(2) acquisition and financing costs, and
(3) installation/commissioning/training costs.

Purchase costs include assessment of items such as land, buildings, fees, and equipment. Financial costs include alternative sources of funds. The initial capital cost category includes all costs of buying the physical asset and bringing it into operation.

1.2 Life of Asset

The estimated life of an asset significantly influences the life cycle cost analysis. Ferry *et al.* (1991) defined the following five possible determinants of an asset's life expectancy:

- *Functional life is* the period over which the need for the asset is anticipated.
- *Physical life:* the period over which the asset may be expected to be 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.

1.3 The discount rate

As the life-cycle cost is discounted to its present value, a suitable discount rate is selected
Crucial for LCC analysis. A high discount rate tends to favor options with low capital costs, short lives, and high recurring costs, whereas a low discount rate has the opposite effect.

1.4 Operations and Maintenance Costs

The cost of ownership, in many cases, is related to operating and maintenance costs. Estimating operation and maintenance costs is essential for minimizing the total cost of ownership of the asset. In the whole of LCC analysis, estimating the operation and maintenance costs is the most challenging task.

1.5 Disposal cost

This is the cost incurred at the end of the asset's working life when disposing of the asset. The
Disposal costs include the costs of demolition, scrapping, and selling the asset.

1.7 Application of Life cycle costing

Life cycle costing originated in defense equipment procurement in the United States in the early 1960s, and its use has since extended to other areas in the public and private sector. The motivation to use LCC in the military sector was borne out of the fact that the consumer (Government), funds the project and operates the related product, essentially bearing the total LCC covering the major cost elements in all stages of the product's Life cycle (Blanchard, 1986). Management and reduction of the total life cycle cost were therefore of immense importance to the Government. In the commercial sector, LCC related costs are acquisition (purchase or lease), operation, maintenance and support are borne by the customer; in addition, the customer incurs costs when the product is not available for use, that is, '*down time costs*'.

A variety of Life Cycle Cost (LCC) models have been developed and applied in many fields ranging from defense, project management, finance, health, supply chain and engineering. However, LCC knowledge has been established for the evaluation and selection of the most economically viable choice among different alternatives over a period of time, especially throughout the entire life span of the projects under consideration.

The idea or focus of LCC models is to justify the selection of a viable solution based on the overall or total cost within a particular life cycle so as to make an informed and effective decision for the purpose of minimizing the cost of initial acquisition, operation, and maintenance (Chate and Khare.,2016).

An effective LCC model can be applied in engineering for the evaluation and selection of projects based on the most economical and viable criteria. Such applications are summarized in the table 1 below (El-Akruti et al,2013).

Applications of LCC	Objectives Modification
Bid Evaluation	Evaluation and selection of the best alternatives proposed by suppliers. The LCC considers not only the initial acquisition cost but also the operating and maintenance cost and disposal cost. The option with a lower acquisition cost may have a higher O&M and disposal costs. LCC can lead to ascertaining the most economical option.
Affordability Studies	For systems or projects with long-term strategic plans and operating results, LCC investigates and studies the viability of different alternatives.
Design Optimization	To select the best and most economical solution throughout the life span of a system or project, LCC lends itself to studying and identifying various project designs.
Design Trade-offs	This focuses on obtaining the most viable design with the optional performance, effectiveness, time, and LCC of the project manager.
Breakdown Equipment	It considers whether to repair or replace a piece of equipment. LCC compares and evaluates the disadvantages and advantages to select the most viable options of whether to repair or replace.
Source Selection Studies	To select suppliers in the most economical way, the project manager compares the different LCCs of the projects from different suppliers and selects the most viable option.

2.0 OPERATING PRINCIPLES OF LIFE CYCLE COSTING

Life cycle costing aims at minimizing the total project cost; however, the only element of cost in the life cycle cost equation that is well known and clearly identified is the initial capital cost—but it is only the tip of the iceberg (Figure 1). Seeing the tip of the iceberg (similar to the obviousness of initial capital cost) does not guarantee a clear and safe passage around an iceberg. Hidden, underlying substructures of an iceberg (similar to the bulk of other costs associated with life cycle costing for equipment and systems) contain the hazards.

Unfortunately, acquisition costs are widely used as the primary (and sometimes only) criteria for equipment or system purchase decisions. These single purpose criteria are simple to use but often result in poor financial management decisions. Acquisition costs tell only one part of the story—most frequently, the story is very simple that the results may be damaging to the financial well-being of the business organisation.

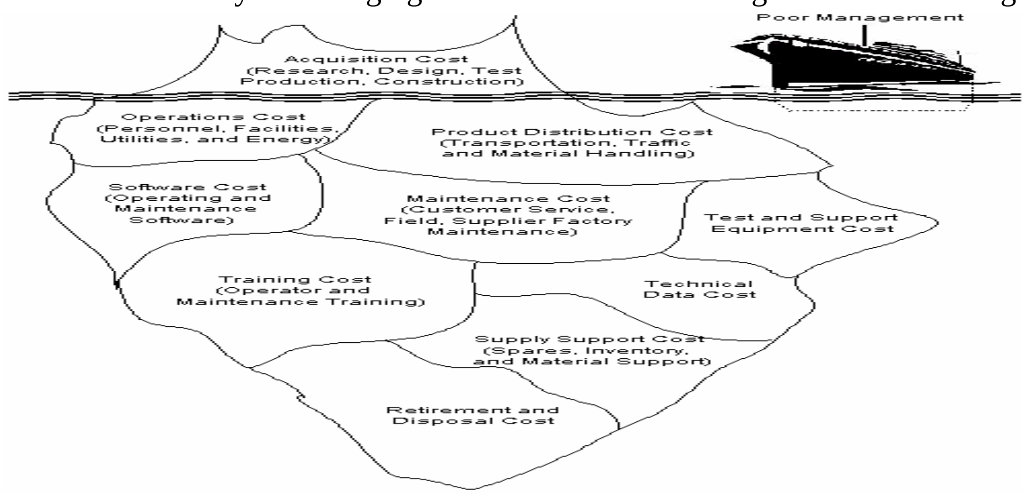

Figure 1. Ice-berg Effect

The basic operating principle of Life cycle costing is attributed to John Ruskins famous quote, *"It's unwise to pay too much, but it's foolish to pay too little. When you pay too much, you lose a little of your money; that is all. When you pay too little, you sometimes lose everything because the thing you bought was incapable of doing the thing it was bought to do." (Barringer* and Weber (1996)).

It is essential to represent the total Life Cycle Cost because the acquisition cost represents only the tip of the iceberg, as shown in figure 1. The part of the iceberg under water carries a huge cost that will be incurred in the future phases of the project. It is therefore pertinent that the total LCC is considered and evaluated to minimize the total cost and not only the acquisition cost.

3.0 Life-Cycle Costing Methodology.

Life-cycle costs (Kerzner,1998 and Blanchard et al,1990) are the total cost to the organization for the ownership and acquisition of the product over its full life. Estimating the total life cycle costs requires a breakdown of the total product cost into its constituent cost elements over time.

The level to which it is broken down depends on the purpose and scope of the LCC study and requires the following identification:

1. Significant cost-generating activity components
2. Time in the life cycle when work/activity is performed
3. Relevant resource cost categories, such as labor, materials, fuel/energy, overhead,

transportation/travel, and the like.

This includes the costs of research and development, production, operation, support, and disposal, where applicable. A typical break-down description may include the following statements:

- R&D costs: The cost of feasibility studies: cost-benefit analyses; system analysis; detail design and development: fabrication, assembly, and testing of engineering models: initial product evaluations; and associated documentation.
- Production cost: The cost of fabrication, assembly, and testing of production models; operation and maintenance of the production capability; and associated internal logistic support requirement, including test and support equipment development, spare/repair parts provisioning, technical data development, training, and entry of items into inventory.
- Construction cost: The cost of new manufacturing facilities or upgrading existing structures to accommodate production and operation of support requirements.
- Operation and maintenance cost: The cost of sustaining operational personnel and maintenance support; spare/ repair parts and related inventories; test and support equipment maintenance; transportation and handling; facilities, modifications, and technical data changes; and so on.
- Product retirement and phase out costs: The cost of phasing out a product from inventory due to obsolescence or wear out, and subsequent equipment recycling and reclamation as appropriate.

Such decomposition is known as a Cost Breakdown Structure (CBS), and an example is presented below in Figure 2.0.

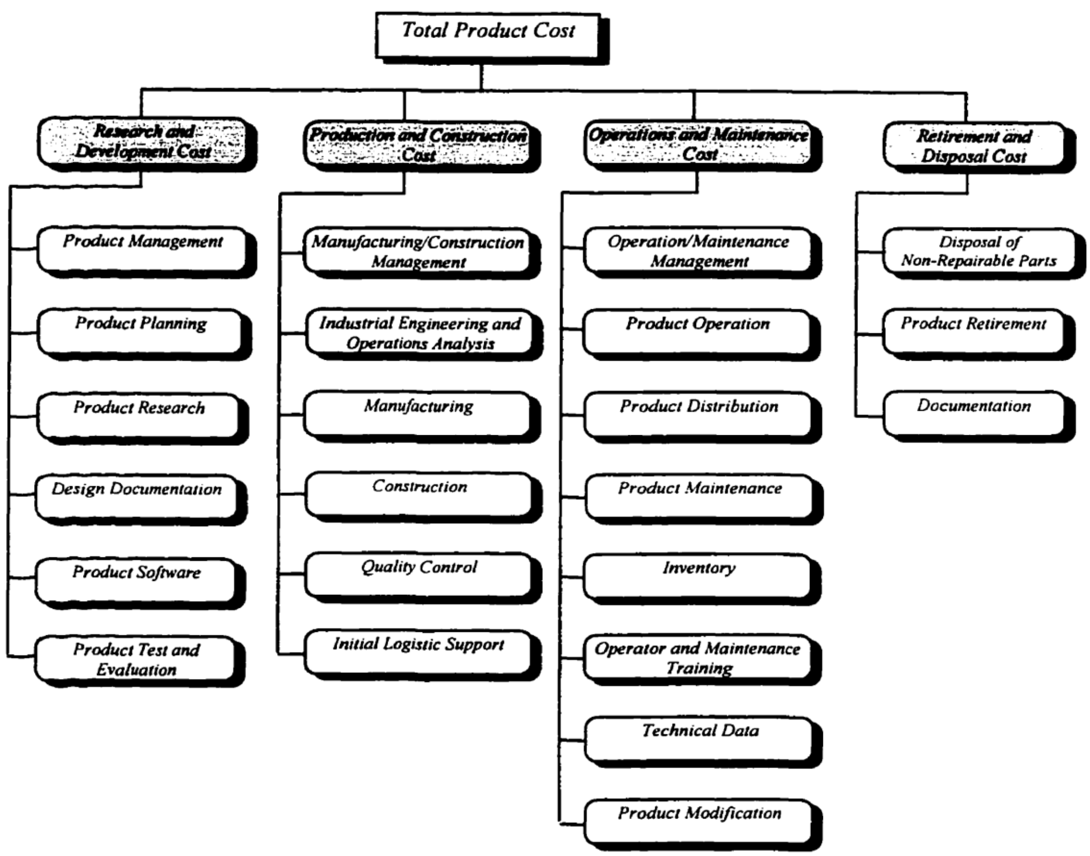

Figure 2.0. Cost breakdown structure (Blanchard and Fabrycky ,1990).

This is, by no means, the most comprehensive and representative of all products or any product for that matter. The level of cost breakdown and categories considered will depend on the design phase in which the model is to be used, the kind of information to be extracted from the model, the data available as input to the model, and the product being designed/purchased. LCC elements may also be estimated in terms of fixed and variable costs. To facilitate control and decision-making and support the life cycle costing process, cost information should be collected and reported in a manner consistent with the defined LCC breakdown structure.

4.0 Estimating Product Cost Elements

The method used to estimate product cost elements in LCC calculations depends on the amount of information required:

• establishing product use patterns, operational characteristics, and the expected product life

• Understanding the technology employed in the product.

4.1 Sources of cost data

By definition, detailed cost data are limited in the early stages of product life, particularly during the design and acquisition phases. Cost data during these early stages must be based on the cost performance of similar product components currently in operation. Where new technology is being employed, data can only be based on estimated unit cost parameters, such as N for construction units and construction units/labor hours specified or suggested by the technology.

Depending on the stage of the analysis and the level of detail expected, an LCC model may be a simple series of Cost Estimation Relationships (CERs) or a set of computer subroutines. LCC analysis during the conceptual or preliminary design phases may require the use of accounting techniques, and the model may be rather simple in construction (Fabrycky and Blanchard 1991). On the other hand, a life-cycle cost analysis performed during the detail design stage may be more elaborate.

Estimating models (Dover 1974, Dhillon 1980, Sherif et al 1981, Dhillon 1983, Gupta 1983, Asiedu 2000, NATO 2007) used in industry can be broadly classified as optimisation, simulation, Calculation/estimation, and decision-support models. These are explained elsewhere.

4.2. Concept of present value (PV)

Costs that occur at different points in the life of a product cannot be directly compared or summed due to the varying time value of money. The present-day equivalent of a future cost, i.e., the present value, can be considered the amount of money that would need to be invested today, at an interest rate equal to the discount rate, to have the money available to meet the future cost at the time when it was predicted to occur. The effects of inflation can also be included in these calculations.

The basic discount equation is as follows:

$$PV = \frac{FV}{(1+r)^n} \text{---------------} 1.0$$

Where:

PV = present value of product or system

FV = future value

r = the decimal discount rate (interest rate)

n = future years

LCC according to TG4 Report (2003**)**: LCC is calculated as the present value of the accumulated annual future costs (C) over a period of analysis time (t), e.g. 60 years (N), at an agreed discount rate (r), e.g. 2% = 0.02 pa, depending on prevailing interest and inflation rates.

5.0 Application of the Life Cycle Costing Concept to Selecting Equipment from Competing Manufacturers

From time to time, equipment or system users are faced with selecting the most cost effective equipment or system from numerous competing manufacturers. In such situations, lifecycle costing becomes a useful tool. The application of the life-cycle costing concept in selecting cost-effective equipment from competing manufacturers is demonstrated through an example.

Example. A company using equipment to manufacture a certain type of engineering part is contemplating replacing it with a better version. Four different pieces of equipment manufactured by four different manufacturers were considered for replacement; their data are presented in Table 1.

S/No	Description	Equipment A	Equipment B	Equipment C	Equipment D
1	Aquisition Cost	300,000	270,000	290,000	350,000
2	Equipment Life	10	10	10	10
3	Failure Rate	0.08	0.07	0.06	0.04
4	Failure Cost	2,000	2,500	3,000	1,000
5	Interest rate	6	6	6	6
6	Operating Cost	6,000	7,000	6,5000	8,000
	LCC	?	?	?	?

Table 1

Data for four types of equipment

Determine which of the four pieces of equipment should be procured to replace the existing one with regard to life cycle costs.

Life Cycle Cost Analysis: Equipment A

The expected annual failure cost C of equipment A is given by

$$C = cost\ of\ failure * failure\ rate$$
$$= \$2000 * 0.08$$
$$= \$160$$

where *C* is the equipment's annual expected failure cost.

Using (Bhillon,2100 and Riggs,1968), this value, *PV*, of equipment A life cycle failure cost is expressed by

$$PV = C\left[\frac{1-(1+i)^{-k}}{i}\right] - - - - - - - - - - 2$$

Where;

PV is the present value of the equipment and is the life cycle failure cost.

where i is the annual interest rate.

where k is the equipment's expected useful life in years. By substituting the preceding calculated value and the given data values into Equation 2, we obtain

$$PV = \$160\left[\frac{1-(1+0.06)^{-10}}{0.06}\right]$$
$$= \$1,176.61$$

Similarly, using (Bhillon,2100 and Riggs,1968), this value PVao of equipment the life cycle operating cost is given by

$$PVao = Coa\left[\frac{1-(1+i)^{-k}}{i}\right]----------3$$

Where;
PVao is the present value of equipment A life cycle operating cost.
Coa is the equipment's annual operating cost.
By substituting the given data values into Equation (3), we obtain

$$PVao = \$6000\left[\frac{1-(1+0.06)^{-10}}{0.06}\right]$$

$$= \$44,160.52$$

Thus, the life cycle cost of equipment A is given as follows:
LCC a = PC + PV+ PVao 4
Where;
LCCa is the life cycle cost of equipment.
PC is a procurement cost.
By substituting the given data value and the preceding calculated values into Equation (4), we obtain the following:
LCCa= 300,000+1176.61 +44160.52
= $345, 337. 13
Similarly, the life-cycle costs of equipment B, C, and D were calculated. Thus, the life cycle costs of equipment A, B, C, and D are $345,337.13, $322,808.62, $339,165.37, and $409,175.09, respectively. By examining these values, it is concluded that equipment B should be purchased because its lifecycle cost is the lowest.

6.0 CONCLUSION

In this paper, a brief introduction to the concept of lifecycle costing is provided. In some organisations, functional lines responsible for capital asset investments, operations, maintenance, and discard or obsolescence management are different. Usually, each of these functions has different objectives, leading to sub-optimal performance as well as wasteful expenditure and budgetary overruns. Therefore, there is a need to adopt an 'integrated view' of all these functions and identify cost drivers holistically, so as to optimise expenditure and ensure cost-effectiveness in any product procurement or development. Life Cycle costing provides this integrated view. LCC is finding increasing usage as a systematic approach to ascertaining the total life cycle cost of equipment.

Life Cycle Costing (LCC) has been in use for quite some time in developed countries during acquisition processes by Governments and by large corporations. Government agencies and corporate organisations in Nigeria should apply this methodology and improve its cost visibility and hence cost control.

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