Life Cycle Cost

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Abstract

Life cycle cost (LCC) is an essential technique for evaluating the total cost of ownership between mutually exclusive alternatives. Executive Order 13123 requires government agencies to use life cycle cost analysis (LCCA) to minimize the government's cost of ownership. Unfortunately, many stakeholders do not understand the concept of cost and proceed to reduce *project acquisition (first) cost rather than the total project cost. However, over the life of the project, facility management cost is often two to three times higher than acquisition costs. Therefore, it is essential to design for minimum facility management costs.*

Introduction

Designers, engineers, and constructors are under pressure from owners to minimize total project costs. Unfortunately, many owners do not understand the concept of the total project cost. As a result, they seek to minimize acquisition (first) costs. Economists Alchian and Allen (1977) argued that the term "cost" should never be used by itself; they noted that it should always be identified with "total," "average," or "marginal," so stakeholders would not confuse one with the other. Proper project management minimizes total project cost, rather than acquisition cost. Total project cost is the cost incurred throughout the life of the project. It is the life cycle cost (LCC) or whole life costing of the project, and it includes acquisition cost, facility management cost, and disposal cost (El-Haram, Marenjak, & Horner, 2002).

The tendency to confuse acquisition costs with LCC is widespread. The acquisition cost is the initial project cost. LCC cost is the entire process of project outlays, which extend beyond acquisition costs. Failure to account for all project outlays often leads to the selection of suboptimal alternatives. Therefore, owners need to establish a robust capital project management (CPM) process, with strict guidelines for project evaluation and control, as well as a knowledgeable capital project manager responsible for evaluating and selecting assets with the lowest LCC. Hestermann notes that although purchase price and LCC define the overall financial health of an organization, they are generally depicted on different financial documents, one on the balance sheet on the other on the income statement. Thus, the relationship between them is seldom understood, and often ignored in the search for profitability and efficiency.

The absence of a robust CPM process inhibits valuable stakeholders' inputs into the definition requirement phase and often leads to project fragmentation. Project fragmentation occurs when different stages of a project are viewed as separate entities. When projects are fragmented, stakeholders tend to focus only on their visible costs and underestimate the direct, indirect, and cumulative impacts of their actions. As a result, there is little or no incentive to holistically apply the principles of LCC, because it is more rewarding for each group to minimize the cost that they are responsible for without considering the impact of their actions on total project cost. Thus, in the absence of a holistic framework for managing projects, LCC will seldom be used effectively.

Section 401 of Executive Order 13123 requires government agencies to use life cycle cost analysis (LCCA) in making investment decisions to lower the government's cost and reduce energy and water consumption (Fuller, 2005). Many government decision-makers, however, are not aware that law and Executive Orders require the use of LCCA (EO 13123).

Total Project Cost

Total project cost is composed of total acquisition cost, total facility management (operation and support) costs, and total disposal cost ($C_T = C_A + C_{FM} + C_D$). Jones (1994) and El- Haram, and Horner (2003) indicated that, over time, the high costs of a system are facility management costs rather than acquisition costs. Therefore, they stressed the importance of designing systems that minimize total project cost rather than acquisition cost. It is also important to note that the ability to influence total project cost is highest in the acquisition phase of a project and lowest in the facility management phase (Chasey & Schexneyder, 2000). Thus, project cost minimization must be embedded in the acquisition phase, particularly during the definition requirements process.

Acquisition Cost

Acquisition cost is the initial project cost (the capital cost); it is the outlays incurred prior to putting the asset, or system, in service. Acquisition cost is a function of the project definition requirements. The definition requirements, which also has been labeled requirement engineering, front-end-analysis, logistics engineering, constructability, and so on, is where designers, engineers, and constructors use optimum knowledge and experience in planning, design, procurement, and field operations to achieve the project objectives (Chasey & Schexneyder, 2000). This phase determines the reliability, maintainability, and effectiveness of the project and its components; 80% of an asset or system life cycle cost is "locked" in this phase (Chao & Ishii, 2004). Therefore, it is essential to have a good understanding of how specified assets or systems will perform in the future. That is, failure modes and their effects of potential alternatives (usually two or more) should be evaluated and discussed with stakeholders, particularly facility management personnel, before asset specification. Pinto and Kharbada (1996) indicated that ignoring the environment and stakeholders contributes to project failure. Mearig, Coffee, and Morgan (1999) noted that choices that designers make determine initial and future costs. For instance, choosing vinyl instead of wood siding or concrete over asphalt paving determines initial and subsequent facility management costs. Thus, failure to understand project tradeoffs can significantly affect future maintenance and replacement costs (Chao & Ishii, 2004).

Facility Management Costs

According to El-Haram and Horner (2003), facility management costs may be two to three times higher than acquisition costs. Thus, there is a need for designing projects that minimize facility management costs. El-Haram and Horner noted that integrated logistics support (ILS) embodies a combination of techniques used in the defense, aviation, and oil industries. They use it to select effective maintenance techniques that should be used in the project design stage to minimize future facility management outlays. One of the ILS techniques is LCCA, which uses future management outlays to forecast the cost of ownership of mutually exclusive alternatives. However, future facility management outlays, particularly for newly developed assets, are often unknown. Additionally, facility management data is not readily available, and many designers and engineers lack facility management experience to make realistic assumptions (Gransberg & Douglas, 2005). Hockley (1998) argues for a bottom-up approach to design reliability, whereby designers know why things fail.

Under LCCA, facility management (operation and maintenance) outlays are future expenses, costs incurred after the project has been placed in service (Mearig et al., 1999). Therefore, it is essential to use robust assumptions when using LCCA to compare mutually exclusive alternatives. Reliable LCCA is possible by using historical facility management costs from similar projects or assets as proxy and experiences facility management personnel. Furthermore, deterministic analyses, such as sensitivity and breakeven analyses, can be used to evaluate uncertainty and risk. Sensitivity analysis is a procedure to determine the sensitivity of the outcome of an alternative to changes in its parameters. For instance, if a small change in a parameter results in a substantial change in outcome, the outcome is sensitive to that parameter. Breakeven analysis is the point where total project revenue (savings) is equal to the total cost of the project.

It is important to note, however, that not all future cost categories may be relevant (Mearig et al., 1999). If two alternates incur the same costs, they can be documented as such and not included in the LCC comparison.

Disposal Cost

Disposal cost or residual value is also a future cost and is often challenging to estimate. Disposal cost is the cost, or gain, of getting rid of assets after use. It may include the remaining net worth, as well as the cost of transferring or destroying the assets. Often, however, the disposal cost of assets being compared is assumed to be zero. Nonetheless, it could be positive or negative.

Asset Life

Asset life is the period over which the asset is fully depreciated; it is the useful economic life of the asset, often determined by past historical performance. Therefore, asset life is the period in which the asset contributes directly or indirectly to the future cash flow of the organization. Thus, the level of maintenance, energy usage, and other factors necessary to maintain the usefulness of the asset influences its life determination. The asset life may or may not coincide with the LCCA study period; it is, however, essential to use the same study period when comparing mutually exclusive alternates (Fuller & Peterson, 1995). Consequently, estimated replacement cost should be included for the asset with the shorter life; often, the base cost, adjusted for inflation, is used as a proxy for future replacement cost. When the study period is determined by expected asset life, FEMP rules in 10 CFR 436 require that the typical service period is that of the asset with the longest expected life. For projects subject to FEMP rules, the LCC period cannot exceed 25 years.

Cost Breakdown Structure

To conduct an LCCA, it is necessary to create a structure that facilitates the identification of project costs in each of the life cycle phases (El-Haram et al., 2002). El- Haram et al. noted that the British Standard 5760, part 23, has a cost breakdown structure (CBS) that identifies all relevant costs categories in all appropriate life cycle phases. The life cycle cost breakdown structure has five levels: 1) project level, 2) phase level, 3) category level, 4) element level, and 5) task level. The project level, level 1, has three phases: acquisition, facility management, and disposal. The phase level, level 2, breaks down each of the three phases into their respective cost categories. Acquisition costs are all the costs required to implement the project. Facility management costs are all the costs necessary for operating, maintaining, and supporting the project during its useful life, and disposal costs are the anticipated costs at the end of the project (asset) useful life. The category level, level 3, takes each category and subdivides it into its cost elements. Acquisition costs include construction costs. We disaggregate construction costs into preparation, superstructure, substructure, building services, and other costs. Likewise, facility management includes maintenance costs, which can be broken down into their elements, such as condition-based maintenance, preventive maintenance cost (PM), reactive maintenance (RM) cost, custodial cost, and so on.

Operating costs can be broken down into utility costs, custodial costs, insurance, rent, and so on. The element level, level 4, takes the categories from level 3 and breaks them down into their cost elements. For example, the cost of constructing the superstructure can also be disaggregated into the costs of the building frame, floors, roof, stairs, walls, windows, doors, and other structural elements (El-Haram et al.). El-Haram et al. also noted that the cost of facility management follows the same breakdown. For example, utility costs can be broken down into the cost of electricity, natural gas, water, sewer, and so on. The task level, level 5, is the total cost of all the resources required to complete a task; Figure 1, depicts the resources needed to construct, maintain, and replace a window.

Tradeoffs

It is often assumed that high-quality building or building equipment results in lower future costs; that there is a tradeoff between acquisition and maintenance costs. Ashworth (1996), however, argued that such a tradeoff is not a given. He noted that higher-quality acquisitions might require higher maintenance costs to maintain their high quality. Nonetheless, he agreed that in general good quality material and a higher standard of workmanship often lead to lower future costs. To exploit this tradeoff, designers, engineers, project leaders, and managers must thoroughly understand how, when, and under what conditions items in the design may fail (Hockley, 1998). Therefore, they should have an in-depth understanding of the design and how it will be used in service. Hockley argued that the potential effects of use and abuse that the design will have should be well understood by designers and managers. One way to achieve an understanding of design outcomes is to evaluate the performance f similar projects and to apply ILS techniques, such as failure modes and effect analysis (FMEA), and reliability-centered maintenance (RCM). Teng and Ho (1996) believe that FMEA, which is a technique that identifies potential failure modes, the effects, and the criticality of these failures, should include the activities of both design and operations. RCM is a systematic approach for identifying the most cost-effective maintenance regime for an asset (El-Haram & Horner, 2003).

Life Cycle Cost

LCC is an economical method for evaluating assets that take into consideration all costs arising from owning, operating, maintaining, and disposing of the asset (Fuller & Peterson, 1995). It is the total discounted cost of acquiring, operating, maintaining, and disposing of an asset over a fixed period (Mearig et al., 1999). LCCA is a useful aid for comparing the lifetime cost of mutually exclusive assets to determine which asset provides the best value per dollar spent (Ashworth, 1996; Mearig et al., 1999; Robinson, 1996), and it should be performed early in the design process. Ashworth, however, does not believe that previous LCC calculations have produced reliable forecasts. He noted that estimated values might be quite different from actual values and that attempting to estimate far in the future could lead to forecasting errors. El-Haram & Horner (2002) indicated that due to unreliable data, it is difficult to define exact costs or each expense category - acquisition, facility management, and disposal. Barringer and Weber (1996) noted that LCC is not an exact science; outputs are only estimates, and estimates are not accurate. Nonetheless, given robust and realistic assumptions, LCC is an essential tool for ranking the cost of ownership between mutually exclusive alternatives. Realistic assumptions can be obtained from evaluating the performance, over time, of similar assets, conducting literature reviews, gathering information from manufacturers, vendors, contractors, and using average support and maintenance costs (Robinson, 1996). Moreover, ILS requires that vendors and contractors identify the physical requirements for support of new assets or systems before the owners approve the acquisition (Jones, 1994).

The period (useful life) associated with LCCA must be well established and historically accurate.

Additionally, the associated discount rate should be used with care since there are differences between real and nominal discount rates. The former excludes inflation, and the latter includes inflation. Thus, when comparing alternatives in a given period, the same discount rate must be used. Furthermore, the discount rate is likely to change from period to period, and there are many discount rates. When using the real discount rate in present value (PV) calculations, cost should be expressed in constant dollars (Mearig et al., 1999). Taxes and depreciation allowances should be accounted for in LCC calculations, as well as any local value effect. Generally, the straight-line method of depreciation is used. It is simple to use, and it is based on the principle that each period of the asset life should depreciate equally. The value effect refers to the market differential response to one alternative versus another. For example, rental for buildings with carpet flooring is higher than for vinyl flooring.

PV is represented as:

$$PV = \sum_{t=1}^{t} \frac{CF}{(1+k)^t}$$

where:

PV = present value
CF = cash flow
k = cost of capital
t = time, Years

Net Present Value Calculation

The net present value (NPV) is one methodology used to determine LCC; it is also used for capital budgeting, where projects with the highest NPV exhaust the firm's fixed investment funding (Branson, 1979). NPV is the present value of an investment's future cash flow (CF) minus the initial investment (I). For many LCCA, however, cash flows are often negatives (outflows). Therefore, the smallest negative, which is the highest NPV, should be selected. The following formula is used to calculate NPV:

$$NPV = \sum_{t=1}^{t} \frac{CF}{(1+k)^t} - I$$

where:

NPV = net present value
CF = cash flow
I = investment
k = cost of capital
t = time, Yrs.

Robinson (1996) used Table 1 to demonstrate LCCA for vinyl tiles floor covering. He noted that the initial installation cost was $37.00 per square meter. A diminishing rate of 25% per annum was used for tax depreciation allowance with a balancing adjustment of $2.08 in the final year. However, as indicated above, most LCC calculations use the simpler straight-line depreciation.[1]

Robinson used the average contract cost to determine recurring cleaning and maintenance costs, which was $32 per square meter. Additionally, he made an allowance for the value effect of $10.00 per m_2 per annum. Table 1 can be used in combination with Excel spreadsheets to determine NPV.

Data Barriers

The principles of LCC have been demonstrated theoretically (El-Haram et al., 2002). However, practical implementation has been difficult due to unreliable and limited data. Additionally, financial complexities, such as interest rates, inflation rates, and tax rates, also inhibit implementation (El-Haram et al.). These barriers, however, are not insurmountable. For instance, El-Haram et al. noted that a comprehensible, consistent, and flexible framework for collecting LCC would mitigate unreliable and inconsistent data. Thus, it is possible to develop accurate acquisition costs and to use historical costs to predict facility management costs, as well as disposal costs.

Managerial Barriers

Most managers identify the acquisition (capital) phase of a project as the total project cost. As a result, they minimize what they perceive as total project cost, which is merely acquisition cost. However, the acquisition phase, where requirements are defined, locks in the asset, or system, future reliability, and hence outlays. Thus, it is important to understand the impact of the acquisition phase on the total cost of ownership of the asset or system. The total cost of ownership is also affected by the way assets are operated and maintained. For instance, buildings, building equipment, and custodial services that are allowed to decay will result in different LCC profiles than well-maintained facilities assets (Ashworth, 1996). Thus, when the project scope is not well understood, implementation results in disparate intra-organizational goals, which lead to the minimization of partial and not total project costs, such as minimizing acquisition cost without regard to the future effects on operation and maintenance costs.

Conclusion

It is important to understand the concept of the total project cost to prevent equating total project cost with acquisition (capital) cost. Total project cost is all the forsaken options the project incurs and those it forces others to bear. If the project specifies and installs floors that are difficult to maintain, it will either result in increased custodial costs or aesthetic problems that could affect employees' productivity. Alchiam and Allen (1977) noted that costs, such as aesthetic problems, are not always measured by the expenditure of claims on marketable resources by paying money. As a result, too often, costs due to inappropriate design are not borne by the design team and project managers; instead, they are transferred to users and operation and maintenance personnel. Finally, poor design frustrates users, operation, and maintenance personnel, and is often difficult and costly to correct. Therefore, stakeholders should meticulously review the design proposal to ensure that the designers conducted and documented appropriate ILS analysis.

[1] See Barringer's free LCC Excel file at http://www.barringer1.com/lcc.xls.

Table 1

Life Cycle Cost Calculation for Vinyl flooring Material (Robinson, 1996)

	Year											
	0	1	2	3	4	5	6	7	8	9	10	11
Capital costs												
Initial cost ($)	37.00											
Replacement cost ($)												
Value effect												
Reduced rental value ($)		-10.00	-10.00	-10.00	-10.00	-10.00	-10.00	-10.00	-10.00	-10.00	-10.00	
Recurring costs												
Cleaning ($)		-32.00	-32.00	-32.00	-32.00	-32.00	-32.00	-32.00	-32.00	-32.00	-32.00	
Tax depreciation allowances												
Initial installations												
Written down value ($)	37.00	27.75	20.81	15.61	11.71	8.78	6.59	4.94	3.70	2.78	2.08	
Balancing adjustment ($)		-9.25	-6.94	-5.20	-3.90	-2.93	-2.20	-1.65	-1.23	-0.93	-0.69	
Tax												
Taxable income ($)		-51.25	-48.94	-47.20	-45.90	-44.93	-44.20	-43.65	-43.23	-42.93	-44.78	
Tax benefit ($)			18.45	17.62	16.99	16.52	16.17	15.91	15.71	15.56	15.45	16.12
Net cash flow ($)	37.00	-42.00	-23.55	-24.38	-25.01	-25.48	-25.83	-26.09	-26.29	-26.44	-26.55	16.12
Net present value		-256.43										

Notes: Taxable income = reduction in rental value less clean cost less depreciation = -$10.00 - $32.00 - $9.25 = -$51.25 in year 1.
Net cash flow = reduced rental value less cleaning cost plus tax benefit = -$10.00 - $32.00 + $18.45 = -$23.55 in year 2.
Tax benefit = $51.25 x 36% applied in the following year to reflect the lag in the payment of tax = $18.45 in year 2.
Net present value = net cash flow discounted at 3.2% (5% after tax @ 35%).

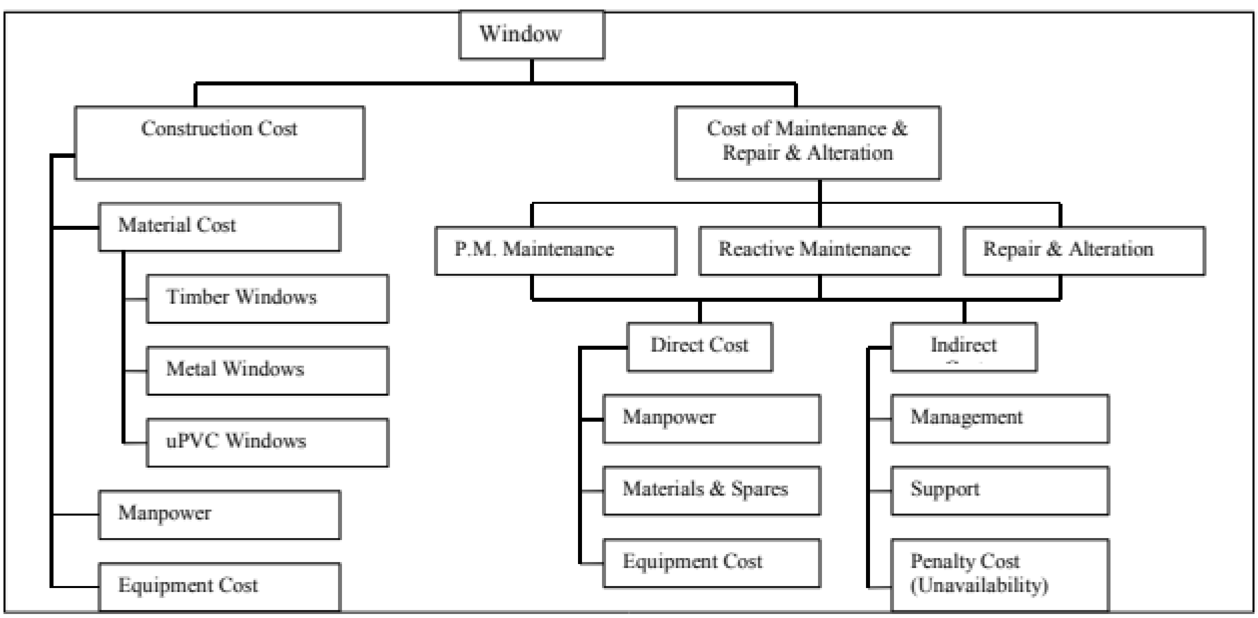

Figure 1. El-Haram, Marenjak, & Horner (2002) Level 5-breakdown structure of the task level

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