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Pump Life Cycle Cost, its Application in Ogorode Steam Electric Power Station

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Abstract: In today's cost conscience business world, understanding the complete cost of a technology-based business solution is as critical as selecting the right technology platforms. Life Cycle Costs (LCC) is a process to determine the sum of all the costs associated with an asset or part thereof, including acquisition, installation, operation, maintenance, refurbishing and disposal costs. This study gives a guide to LCC analysis for pumping system in Ogorode steam power station. Station management only considers the initial purchase and installation cost of a system. Hence, it is the objective of this paper to stress the need to evaluate the LCC of carrying out a major and equipments or carrying out a major overhaul. By evaluation 2 pumps A, B, the most financially attractive alternative was identified. Hence, it is better to consider all relevant costs to determine the LCC and optimize preventive maintenance during early stages of acquisition of an asset. NPV was used to arrived at a practical application and selection of the two pumps.

Key words: Life cycle cost, application Ogorode electric power station, implementation

INTRODUCTION

With growing pressure to achieve better outcomes from assets, ongoing operating and maintenance costs must be considered as they consume most resources over the asserts service life. LCC is the comparison of alternative investments using the entire cost of owning and operating the equipment. If the analysis is done right and all factors are addressed and the information is good, the item that cost the least amount to own (buy and use) over its working life will be selected. The equipment when compared to other suitable items would perform its lifetime service at least total cost to the power station. A low LCC means that the least amount of money necessary was spent on it, while a high LCC means extra money was spent and that money was then not available for other things. From a purely financial viewpoint it is necessary to go for equipment with the lowest LCC possible. LCC is used for planning for reliability and maintainability in power stations.

Although pumps are typically purchased as individual components, they provide services only when operating as a part of a system in the power stations. The energy and materials used by a system depend on the design of the pump, the operated. These factors are interdependent. They must be carefully matched to each other and remain so throughout their working lives to ensure the lowest energy and maintenance costs, equipment life and other benefits. The initial purchase price is a small part of the life cycle cost for high usage pumps.

Pumping systems account for nearly 20% of the world's usage in certain industrial plant operation. While operating requirements may sometimes override energy cost considerations, an optimum solution is still possible. A greater understanding of all the components that make up the total cost of ownership will provide an opportunity to drastically reduce energy, operational and maintenance costs. Reducing energy consumption and waste also has important environmental benefits.

LCC analysis is the most rational, objective method for selecting the optimum pump system for a power station. Through LC analysis, all factors that influence total system cost can be identified and quantified. Subjective factors such as fuel cost adjustments, component reliability and maintenance costs are also included. LCC analyses can be used to assess the economic consequences of any decision by comparing two or more alternatives. A review of annual cost of pumping system for the electric power system shows high impact of energy costs. The energy cost is about 30-35%

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of the electric energy usage in the power station. LCC is a management tool that can help the power station minimize waste and maximize energy efficiency for any type of equipment including pumping systems. This study provides highlights for pump LCC and to assist the Ogorode power station implement LCC. The LCC methodology involves adding up all the costs of the pumping system over the term of the evaluation with the costs in any year being discounted back to the base period. The discounting process seek to reflect the time value of money and to reduce all future sums of money to an equivalent sum of money in the base period e.g. in today's dollars, or dollars at the purchase of the pump. The discounting process estimates the present value of future costs. The standard form of the assumptions is made in this approach:

- Initial capital costs are considered as a lump sum at the start of the analysis (i.e. in period O).
- Other non-recurring costs such as replacement of plant and equipment may be required during the period of the analysis.
- All recurring costs (e.g, energy, costs and operating and maintenance costs) begin to accumulate in the first period (i.e., the period after period O).
- Costs in any period are lumped together and are considered to occur at end of that period.
- Inputs such as salvage values are considered as negative costs and
- The rate at which costs increase may differ between energy and other recurring costs.

Background of the problem: The Nigeria electric power stations only consider initial purchase and installation cost of any system investment. It will be fundamental interest of the station managers to evaluate the LCC of different solutions before installing major new equipment or carrying out a major overhaul. This evaluation will identify the must financially attractive alternatives. As the deregulation and other independent power provides continue to competite with the Nigeria electric power stations and in particular, Ogorode steam power station, must continually seek cost savings that will improve the profitability of their operations. Since plant equipment operations are reoccurring, particular attention as a source of cost savings, minimizing energy consumption and plant downtime need to be considered at the early stage. The existing systems in Ogorode power station will provide greater opportunities for saving through the use of LCC methods. There are many pumps installed in the power station to transfer fluids or near fluids. Many of these existing plants have pumps controls that are not optimized. The hydraulic Institute studies have shown that 30 to 50% of the energy consumed by pumps system could be saved through equipment control. If the issue is only the lowest acquisition cost, then alternatives should not be bothered-even if the higher first cost alternatives are more beneficial. But the issue is lowest long-term cost of ownership, hence, the alternatives.

Life Cycle Costs (LCC) Analysis: A basic requirements of pump is the ability to provide long-term performance with a minimum of down-time and cost associated with maintenance. As a result LCC is of particular importance to the power station. LCC analysis will provides a more secure basis for comparing and selecting pump options than the traditional method of judgments based on comparing acquisition costs alone. This particularly applies to situations where the initial costs is high and downtime for unplanned maintenance is costly. In circumstance where pump is being considered or introduced into new field of applications, comparisons are often made not only on initial costs. Here the reasoning should progress well beyond the simple initial cost comparison and take account of the long term cost assessment associated with this assessment.

The goal of the analysis is to select from a set of alternatives the pump with the lowest life cycle cost. Life cycle costings are the cost elements that must be considered when the Nigeria electric power stations want to estimate the complete LCC associated with a given asset. LCC will help the power stations justify equipment and process selection based on total costs rather than initial purchase price. Barringer (2000) points out that the sum of operation, costs. Decisions made during the early stages of a project for the life cycle cost analysis, the following steps and actions are necessary:

- Define cost analysis goals;
- Action to be taken
- Clarify analysis objectives
- Define critical items; and
- Bound the analysis problem
- Reliability consideration:
- Determine optimum values of MTBE that minimize total LCC. Alternatively, determine the best value of MTBF that meets overall assets performance and set objectives.
- Identify guidelines and constraints
- Action to be taken
- Evaluate alternative resources
- Determine schedule constraints;
- Identify management policy and
- Identify technical constraints

Available resources will determine how thorough the reliability programme can be, particularly in the design, analysis and test areas. Operation and maintenance resources should be directly related to the level of achieved reliability. Resource limitations are function of perceived or actual scheduled constraints and management ability or willingness to convert resources. Outsourcing is a potential solution.

- Identify feasible alternatives:

Actions to be taken

- Consider all possible approaches;
- Further evaluate possible alternatives and
- Eliminate non-attainable alternatives

Reliability considerations: Evaluate all possible approaches to implementing a reliability programme, given the defined guidelines and constraints. Elements of reliability approaches are not excluded unless they are proved to be unattainable.

- Develop cost breakdown structure

Actions to be taken:

- Identify all LCC elements;
- Identify major cost categories;
- Break costs down to appropriate level;
- Code relevant cost areas;
- Categories cost code areas and
- Assure compatibility of code structure

Eliability-related cost elements are difficult to obtain and may be interspersed among several technical disciplines, particularly during the RIO and design analysis stages. The degree of detail in a company's cost accounting structure will dictate the level to which LCC cost element data can be obtained.

- Select or develop cost model

Actions to be taken

- Investigate current available models and
- Construct new model s (if accessory).

Selected model must address both the acquisition and O and M cost elements and must allow sensitivity analysis based on reliability parameters, in order to obtain valid LCC impacts.

- Develop cost estimating relationships

Actions to be taken

- Identify necessary input data; and
- Develop supporting cost data
- Reliability considerations
- Cost estimating relationship should be developed based upon data dependency on MTBF
- Develop life cycle cost profile

Actions to be taken

- Identify cost generating activities
- Relate each activity to a cost category;
- Establish constant dollar cost factors;
- Project individual cost elements into the future;
- Factor in inflation, learning curves, price levels and
- Summarises individual cost systems into top level cost profile.

Reliability considerations profiles should reflect varying levels of reliability programme activity, dependency upon the programme phase, the extent of operation and maintenance definition and the type/depth of analysis being performed. Cost profiles must reflect reliability-related activities occurring in all technical and non-technical disciplines.

- Perform sensitivity analysis

Actions to be taken:

- Varify critical parameters;
- Assess impact on cost categories; and
- Assess impact on LCC.
- Reliability considerations;

Cost sensitivity to MTBF, which reflects the integrity of the reliability programme, should be the major driven to assess individual cost category and total LCC imipacts. Note effects on changes in the total LCC for optimization.

- Select best value alternatives:

Actions to the taken

- Choose the alternative which maximizes reliability at minimal cost to reach operation and maintenance performance objectives.

Reliability considerations may need to trade-off reliability performance to meet operations and maintenance objectives (cost, schedule and technical). Sensitivity analysis should identify suitable alternative choices.

The Net Present Value (NPV): Life Cycle Costs (LCC) refers to all costs associated with acquisition and ownership of plants and equipments or system over its full life (Fabryck and Blanchard, 1991). The useful figure of merit is NPV.

NPV is a financial tool for evaluating economic value added. It is the present value of an investments future met cash flows, minus the initial investment for a given discount rate hurdle. The present values for each year of operation and maintenance are summed for the NPV. Net cash flows are a measure of a company's financial health. Discount rates are the rate used in discounting future cash flows (Barringer, 2001). For the enire equipment and plant, life, the LCC number requires a positive NPV. Barringer (2001) points out that plants and equipment cannot easily show profit/savings for each component. Thus decisions are made in selecting equipment based on the least negative NPV. The least NPV is better. All LCC task require comparisons of alternatives.

Barringer (2001) maintains that in every LCC task, conflicting issues are obvious such as:

- Project engineers want to minimize capital expenditures;
- Accounting want to maximize NPV;
- Production wants to maximize uptime hours;
- Maintenance engineers want to minimize repair hours
- Reliability engineers want to avoid failures.

All parties want someone else to put numbers together to justify their commitments with project or equipment, which justifies their decisions. Business is about time, money, an alternatives. The LCC concept merges time and money together to arrive at a single indicator called NPV for each alternative. NPV numbers prioritorizes the equipments to select the winner from the alternatives so that the right one is bought rather than the cheap one. Also engineering need to be added to the NPV for issues concerning operability, maintainability and reliability, which can alter effectiveness of the system.

Data for LCC: Often acquisition cost is the only number in the life cycle cost analysis in the Nigerian electric power station which is well defined by a bid price. Other details of acquisition cost must be estimated from facts usually available within the business system. Scaling data up/down for specific cases is a well-established method. Assembling cost details by year of fairly meticulously as front-end money has greater impact than the same money spent in the last year of the equipment such as occurs within end of life issues (Barringer, 2001).

Making the LCC calculations is easy when there is available data. The difficult effort is how to resolve the problem for finding failure data, maintenance data and other details involved in the sustaining costs. Reliability engineering details are needed to paid when equipments fail. Failure data and repair data can be converted into statistical format using Winsmtih Weibull software for use in reliability calculations (Fulton, 2000). Follow the scientific method.

Method: build a hypothesis for failures and their costs and the test the hypothesis. When indoubt about the failure data or cost, make an estimate and test for validity (Barringer, 2001). Much data needed for the LCC comes form operating costs and maintenance records which show time between failure and repair times. This details are often associated with the field of reliability and maintainability with a direct relationship with finding lower LCC (SAE, 1999). The cost details should also include costs for cost gross margin for outages of system when it is appropriates. Reference books and data bases with extensive failure details are available at the internet (Barringer, 2000) and training manuals (Barringer, 2001). Some of the failure data is from simple arithmetic calculations and other data follows the preferred method from Weibull databases (Abernethy, 1999).

Failures and failure cost can be influenced by operating condition, installation conditions and maintenance conditions. There are different grades of influences for and against longer life. Often available conditions require Monte Carlo simulations to find how costs will vary with time and the differents grades of interface. The Monte Carlo techniques uses random numbers to solve the problems and spreadsheets are available. (Barringer, 1999). More extensive models are available (Barringer, 2000c). Building a low cost Monte Carlo reliability models using software which is useful for driving LCC decisions is available from internet (Barringer, 2000c). The reason for building reliability models is to find where reliability cost is occurring and to search for the longest long term cost for ownership where system details, when priced out provide a clear leading alternative for solving the problems. The reliability model shows what's affordable and less desirable, using actual failure data and repair times will give system availability, reliability, maintainability and other operating system details which allows constructions of costs and trade-offs (Barringer, 2000d). The reliability modes provide evidence for trade boxes. Engineers need graphics for understanding what's happening to the systems. The trade-off box has LCC on the vertical axis and effectiveness on the horizontal axis. Effectiveness is the product of availability, reliability, maintainability and capability of the system to perform (Barringer, 2001).

Table 1:Cost of capital at 12%

	Discount rate = 12%								
Years	10	1	2	3	4	5	6	7	8.0
Present value of $1.00	1.0	0.89	0.8	0.71	0.64	0.57	0.51	0.45	0.40
Future value of $1.00	1.0	1.12	1.25	1.40	1.57	1.76	1.97	2.21	2.48

Case study: Ogorode steam power station wanted to purchase a water pump. There were two options to select from. Pump A has a capital cost price of $7,700,000 and the associated costs of maintenance were as follows: 5% of the capital cost per year for the first 5 years, 10% of the capital cost per year for the next 5 years. Pump B has a capital cost of $9,750,000 and has a projected maintenance and operation costs as: 21/12% of installed value for the first five years and thereafter increasing per year by 5% of the capital cost. Each of the pumps are of the same capacity and had an economic life of 8 years. The cost of capital is 12% in each case.
Table 1 shows cost of capital at 12%.

In order to compare alternatives based on discounted cash flow, the time value of money is taken into account, that is, the amount of X dollars spent now that will be equivalent to the same amount in future.

The NPV concept could be used in this case in which an $X(1\text{-}i)^t$ needed now would be regarded as equivalent to an amount X spent t years from now if the interest rate is i.
Similarly a cash flow of amount X_o, X_1, X_2, …, XN at each start of each N consecutive years would be equivalent to a sum of :

$$\begin{aligned} Y(N) &= X_o(+i)^o + X_1(1+i)^1 + X_2(1+i)^2 + \dots X_{N-1}/(1=i)^{N-1} \\ &= \sum_{t=o}^{N-1} X_t/(1+i)^t \end{aligned} \tag{1}$$

For the LCC problem, if Y(N) denotes the NPV of the cash flow that will result from keeping the pumps for N years, then, NPV must be chosen which gives the least value. This is continually done by finding a value for Y(N) dollar paid at the beginning of year O, year 1…, year N which will be equivalent to the original cash flow, then the least of the fixed equivalent cost" in the N year is the preferred LCC.
The present value of the cash flow of fixed amounts $\bar{Y}(N)$ is

$$\bar{Y}_{(N)} = V^o\bar{Y} + V^1\bar{Y}_{(N)} + V^2\bar{Y}_{(N)} + \dots V^N\bar{Y}_{(N)} = A_N\bar{Y}(N) \tag{2}$$

Where V = 1/(1+i) and

$$A_N = Vo + V1 + V2 + \dots + VN = \sum_{i=o}^{N} 1/(1-i)^t \tag{3}$$

But since the present value and the fixed cash flow are equivalent, the present value of equation (2) must equal Y(N). that is

$$A_N \cdot Y_{(N})= Y_{(N)^*}. \tag{4}$$

$$\therefore \quad Y_{(N)^*} = Y_{(N)}/A_{N^*}$$

Note that is analogous to the arithmetic average of the amounts of cash flow. In fact, for i = o implying no interest rate on money, becomes precisely the arithmetical average obtained if it does not take into account time value of money i.e.,
Where

LCC = First cost plus all future costs (operating, maintenance, repair and replacement costs and functional = use costs) minus salvage value (i.e. value of an asset at the end of economic life or study period.

While the optimal replacement cycle for an equipment involves determining the optimal number of years (or age) that an equipment may be profitably used before being scrapped.

Given the price of the equipment, the cost of funds (i.e.,) interest rate or discounted rate) and all the relevant cash flows, operating, maintenance and other costs associated with the equipment, many different models could be developed for solving the equivalent replacement problem.

In one such model, the optimal replacement age is denoted by solving the function:

$$\bar{Y}_{(N)} =^{\min(n)} \left[\left\{ \sum_{t=o}^{n} x_t/(1+i))^t - S_n/(1=i)^n \right\} / A_n \right] \tag{5}$$

Where
X_o = The purchase price of a new equipment at year
t = 0 (for existing equipment, x_o represents overhaul cost at any point in time to give the old equipment a new lease of life".
X_t = Annual total operating, maintenance and other costs at year t.
A_N = $\sum_{t=o}^{n} 1(1+r)^t$, the annuity factor at t = n and n is a candidate value for the optimal replacement age N.
S_n = The salvage value at the end of year n
i = The users cost of funds (i.e., interest or discounted rate).

Table 2: Computation of LCC of pump A

t	x_t	PV factor	FV factor	FV
0	7,700,000	1	1	7,700,000
1	6,853,000	0.89	1.12	8,624,000
2	6,160,000	0.80	1.25	9,625,000
3	5,852,000	0.76	1.40	10,780,000
4	4,697,000	0.61	1.57	12,089,000
5	4,389,000	0.57	1.76	13,552,000
6	3,927,000	0.57	1.97	15,169,000
7	3,465,000	0.45	12.21	17,017,000
8	3,080,000	0.40	2.48	19,096,000

Table 3: Maintenance + operation + repairs /replacement for pump A

t	Amount	PV factor	PV	FV factor	FV
1	375,000	0.40	15000	2.21	828,750
2	375,000	0.51	19,1250	1.97	738,750
3	375,000	0.57	213,750	1.71	641,250
4	375,000	0.64	214,000	1.57	588,750
5	375,000	0.71	266,250	1.40	525,000
6	750,000	0.8	600,000	1.25	935,500
7	1,120,000	0.89	996,800	1.12	1,254,400
8	1,495,000	1.00	1,495,000	1	1,495,000
	Total		3,992,050		7,009,400

Table 4: NPV, FV and LCC of pump A

	NPV	FV
Acquisition cost	$3,080,000	$19,096,000
Sustaining cost (maint+Op +repair/replace)	$3,992,000	$7,009,400
LCC	$7,072,000	$26,105,400

Table 5: Computation of Pump B LCC

t	X_t($)	PV factor	FV factor	FV ($)
0	9,750,000	1.00	1.00	9,750,000
1	8,677,500	0.89	1.12	10,920,000
2	7,800,000	0.8	1.25	12,187,500
3	6,922,500	0.71	1.40	13,650,000
4	6,240,000	0.64	1.57	15,307,500
5	5,557,500	0.57	1.76	17,160,000
6	4,972,500	0.51	1.97	19,207,500
7	4,387,500	0.45	2.21	21,547,000
8	3,900,000	0.40	2.48	24,180,000

Table 6: Maintenance + operation + repair/replacement

t	Amount ($)	PV factor	PV ($)	FV factor	FV ($)
1	243,750	0.40	97,500	2.21	538,688
2	243,750	0.51	124,313	1.97	480,188
3	243,750	0.57	138938	1.76	429,000
4	343,750	0.64	15,600	1.57	382,688
5	730,750	0.71	173063	1.40	341,250
6	121,7750	0.80	584,600	1.25	730750
7	1,705,250	0.89	1,022,910	1.12	1145659
8		1.00	1,705250	1.00	1705250
	Total.		$ 3,587,050		$ 5,154,609
			3,900,000		24,180,000
					5,154,000
			7,487,050		29,334000

Table 7: NPV, FV and LCC of pump A

	NPV	Fv
Acquisition Cost	3900,000	24,180.000
Sustaining cost(maint+ OPS +repair/replacement)	3,587,05	5,154,000
LCC	7,487,05	29,334,000

Table 8: Comparing the two pumps

	Pump A	A	Pump B	
	PV	FV	PV	FV
Acquisition costs				
Sustaining cos t	$19,096,000	$3,080,000	$3,900,000	$24,180,000
	$3,992,000	$7,009,400	$3,587,050	$ 5,154,000
	$7,072,000	$ 26,105,400	$7,487,050	$ 29,334,000

Difference $ 415,050

Solving function (5), gives an optimal replacement cycle of N years period. If the resale or salvage value, S_n, of the equipment at a time n is zero, then replacement problem reduces to solving the equation.

$$Y(N) =^{\min(N)} \left(\sum_{t=o}^{n} X_t / (1+i)^t \right) / A_n \tag{6}$$

which is known as solving the equivalent economic life problem. The economic life , N, of the equipment is fixed when the present value of the combined capital, maintenance, operating and other costs of the equipment as a function of years of service is a minimum. Y(N) is thus referred to as the fixed equivalent cost of the equipment. The notion of the economic life is that an equipment reaches the end of its economic life when its current operating maintenance and other costs exceed the combined capital, operating, maintenance and other costs of a new equipment. The fixed equipment cost method is used in equipment replacement decisions as a means of normalizing the irregularities of costs and times of payment.

Table 2 Shows the computation of LCC of pump A. While Table 3 and 4, respectively show the sustaining costs and NPV, FV and LCC fof pump A.

Also Table 5-7 show the computation of LCC, sustaining cost and NPV, Fv and LCC for pump B.

Table 8 shows the comparism of pumps A and B

RESULTS AND DISCUSSION

Using the discount rate of 12% shown in table 1. the following values were considers, FV = Pv $(1+i)^n$ where Fv is the future value, PV is prevent value I, is discount rate and n is number of years into the future; the value of $1 today PV is shown on Table 1 and the future value of $1 is also shown even time. The discounted method is used to show the cash outlay over the life of the two pumps in terms of present or future value allows. Discount sates in Table 1 are used as multiplies or divides to put financial position in the present of future value of money.

The LCC calculation for cash of the two pumps are summarized in Table 8. Pump A has lower LCC and is the preferred option of the two. However, pump B has a lower sustaining costs but higher acquisition costs. The difference of $ 415,050 resulting in the LCC of the two pumps justifies the preferred choice of pump A.

CONCLUSION AND RECOMMENDATION

This study has considered the LCC of two pumps, A and B in Ogorode steam power station in Sapele. Without the use of LCC in acquisition and decision of an equipment, an irrational decision could be made.

However, it is better to use a prediction based on proven LCC models in order to ascertain the economic advantages in the alternatives. As LCC are spaced over many years they must be converted to a common value, the present or future value in order to make them comparable over a period of time. In converting future values to present values, discounting is performed by applying interest (discount) formulae to the estimated costs or benefits of a given equipment investment. The main idea behind discounting is that it should reflect the fact that today's money is worth more than tomorrow's money that is, it can earn interest in selecting an opportunity cost of investment in plant/equipment. Is it often desirable to test its economic feasibility based on alternative values of key parameters, e.g. life of the equipment, operating maintenance, repair and replacement etc. it is also important to know the values or range of values of parameters that reflect the LCC analysis.

LCC should be a valuable method for tracing the cost consequences of various alternatives investments in equipments in Ogoiode steam power station with long life spans. It should be used in the power station as a tool to determine the feasibility of alternative systems in plants/equipment retrofits. Because the application of LCC requires prior specification of several parameters and a considerable amount of prediction about them, the limitation of the method must be clearly understood. Efforts should be made by the power station management to improve its value by developing data bank on the various components of the LCC.

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